# The development of fermented pea protein-coconut milk beverage

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# ABSTRACT

Most commercially available probiotic products are dairy-based and are associated with consumer health challenges such as lactose intolerance and allergenicity due to milk proteins. Therefore, a strong consumer interest in searching for alternative products and ingredients that can deliver similar health benefits to dairy-based products. Plant protein is an important nutrient for the normal growth and functioning of the human body. Pea protein is of interest to food manufacturers due to its high nutritive value. However, it is characterised by a strong off-flavour (beany flavour) making it difficult to formulate into acceptable consumer food products. The main aim of this study was to reduce the beany off-flavour of commercial pea protein powder intended for the production of an organic fermented pea protein-coconut milk beverage. This research was conducted in three main phases.

In Phase 1, salt extraction and isoelectric precipitation methods were used to further purify commercial pea protein powder (Roquette S85F, France). After purification, the yellow commercial pea protein powder ($b^* = 16.32 \pm 0.09$) had transformed into a white pea protein paste ($b^* = 6.86 \pm 0.12$).

Phase 2 investigated the reduction of the beany off-flavour by fermentation of a novel fermented pea protein-coconut milk beverage. In this phase, the refined pea protein paste (phase 1) was added to organic coconut milk (Ceres Organics, Auckland) and then fermented by a mixed lactic culture (VEGE 053 LYO). The single factor test and orthogonal experimental design were used to determine the optimum fermentation conditions of the fermented pea protein-coconut milk beverage. In these experiments, three fermentation temperatures (37 ℃, 40 ℃, 43 ℃) with three protein concentrations (3%, 5%, 7%, w /v) and three fermentation times (8, 10 and 12 h) were used to conduct nine experimental treatments (formulations). The three best fermented beverages were selected based on viable cell counts (VCCs) and sensory evaluation by a semi-trained sensory panel (n=18). These three best samples were further evaluated by a consumer sensory panel (n=90). The fermented beverage containing 3% pea protein and fermented at 40 °C /8 h was evaluated as the best product by the consumer sensory panelists. The final selected formulation had the highest viable cell counts ($8.78 \pm 0.21$ log CFU /mL) and overall mean sensory acceptability scores ($6.2 \pm 0.50$). Other parameters determined in the final formulation of the fermented beverage were pH, titratable acidity (T.A.), colour and crude protein. During fermentation for 8 h, the pH decreased from $6.15 \pm 0.13$ to $4.29 \pm 0.02$, while the T.A. increased from $0.09\% \pm 0.01$ to $0.52\% \pm 0.03$. Colour changed significantly ($p<0.01$), whereas there was no significant ($p>0.05$) difference in the protein content of the fermented pea protein-coconut milk beverage during fermentation.

In the third phase, the stability of the fermented beverage during storage (4 °C) for 21 days, was determined by measuring pH and colour as well as the analysis of protein and sensory characteristics. A semi-trained sensory panel (n=15) evaluated the fresh and stored beverage for various sensory characteristics including overall acceptance using the 9-point hedonic scale. During storage of the beverage, the pH, titratable acidity, cell counts and colour changed significantly ($p<0.05$). By the end of storage, the pH had decreased from $4.43 \pm 0.03$ to $4.38 \pm 0.02$ ($p<0.05$), while T.A. increased slightly. The sensory characteristics were stable during storage. Despite the changes in the physical-chemical characteristics of the fermented beverage, the product was still found to be acceptable by a semi-trained sensory panel following storage for 21 days.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| a* | = | redness-greenness |
| ANOVA | = | Analysis of variance |
| AOAC | = | Association of Official Analytical Chemist |
| ATP | = | Adenosine triphosphate |
| b* | = | yellowness-blueness |
| B.C. | = | before Christ |
| BCAAs | = | branch chain amino acids |
| BCE | = | Before the Common Era |
| Ca | = | Calcium |
| $CaCl_2$ | = | Calcium chloride |
| $CaCO_3$ | = | Calcium carbonate |
| CFU /mL | = | colony-forming units per milliliter |
| CPPP | = | Commercial pea protein powder |
| DCU | = | Direct Culture Unit |
| etc | = | et cetera |
| F6PPK | = | fructose-6-phosphate phosphoketolase |
| g | = | gram |
| G | = | Gram |
| GC-MS | = | gas chromatography-mass spectrometry |
| GLM | = | general linear model |
| GMO | = | genetically modified organism |
| h | = | Hours |
| HCl | = | hydrochloric acid |
| HPLC | = | high performance liquid chromatography system |
| HDL | = | high-density lipoprotein cholesterol |
| L | = | Litre |
| L* | = | Lightness |
| LAB | = | Lactic acid bacteria |
| LDL | = | low-density lipoprotein cholesterol |
| LOX | = | Lipoxygenase |
| LSD | = | Least significant difference |
| $K_2SO_4$ | = | Potassium sulphate |
| Min | = | Minute |
| mg | = | milligram |
| mL | = | millilitre |
| MCTs | = | medium-chain triglycerides |
| MRS | = | De Man, Rogosa and Sharpe agar |
| NaOH | = | sodium hydroxide |
| P | = | phosphorus |
| pH | = | potential hydrogen |
| Se | = | Selenium |
| SD | = | standard deviation |
| T.A. | = | titratable acidity |
| UHT | = | Ultra-high temperature |
| UV | = | Ultra Violet |
| VCCs | = | Viable cell counts |
| WHO | = | World Health Organization |
| w /v | = | weight per volume |
| µg | = | microgram |

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# 1. INTRODUCTION

## 1.1 Background

Consumer awareness of health and nutrition has markedly increased in the last two decades (Abdel- Rahman, Eltayeb, Azza, & Feria, 2011). Of the ingredients in functional foods, protein is an essential nutrient for health growth and functioning of the human body. Despite the importance of this macronutrient, world protein requirements continue to be a global issue with heightened concerns about food security and protein malnutrition. In 1997 the Food and Agriculture Organisation of the United Nations (FAO) estimated that over 800 million people in the developing world were undernourished (Blandford & Viatte, 1997), and the number continues to increase. As an essential nutrient element in the body, proteins are made of 20 amino acids, some of which can be synthesised in the human body while others must be obtained from food (essential amino acids). Protein is found in both animal and plant sources. Animal sources food which contain high protein content includes meat, seafood, eggs and milk products. Plant protein is mainly found in legumes (peas, beans and lentils), grains (quinoa, oats and barley) and nuts. However, there is increasing evidence that a diet mainly based on animal protein may be linked to indigestion, high blood pressure and heart disease, because of the consumption of high saturated fat (Kaluza, Åkesson, & Wolk, 2015; Choi et al., 2013). Plant proteins are good sources of dietary fiber and are generally low in fat, particularly saturated fats. Diets high in plant protein, such as the vegetarian diet, are associated with many health benefits such as low body weight, low cholesterol and balance blood pressure (Craig, 2010). Therefore, high nutrition value plant-based protein represents a suitable dietary substitution to animal-based protein (Duranti & Gius, 1997). As the demand for proteins in the world is increasing, the need for high-quality protein derived from plants is particularly strong.

Legumes (peas, chickpeas, lentils and beans) are considered inexpensive sources of proteins for low-income groups of the population and are commonly used substitutes for meat. If their application in the food industry can be expanded, legumes can play a significant role in alleviating protein-energy malnutrition (Mateos-Aparico, Redondo, Villanueva-Suarez, & Zapata-Revilla, 2008). Legumes constitute an important source of dietary protein for large segments of the world's population, especially in those countries in which the consumption of animal proteins is limited due to either its non-availability or higher price (Boye, Zare, & Pletch, 2010).

The pea (*Pisum sativum*) is an important legume which has been grown since the beginning of arable farming (7000–6000 B.C.). In New Zealand, it is considered the third most important cash crop of all the legumes (Jermyn, 1983). Growing peas can improve soil fertility as they fix nitrogen into the soil through their roots, reducing the need for chemical fertilizers. Peas are commonly consumed as seeds, flour and protein isolate (Aiking, de Boer, & Vereijken, 2006) which are relatively low in calories and contain several vitamins, minerals and antioxidants. Pea products are also high in fiber and protein (Muehlbauer & Tullu, 1997), making them important to the human diet (White, 1983). However, the commercial application of the pea (especially the yellow pea) is limited by its undesirable colour, unpleasant taste and flavour and low solubility. Therefore, based on available reports (Hansen, Jakobsen, & Christensen, 2000; Murat, Bard, Dhalleine, & Cat, 2013), it is challenging to overcome the undesirable characteristics.

The dark yellow colour of pea protein can be improved by using different refining methods which involve isoelectric precipitation and salt extraction. After extraction, the colour of commercial pea protein powder changes from dark yellow to white and the particle size will be smaller (Scopes, 2013).

The bitter, beany taste and the "green", "grassy", "hay-like" odor profile of pea protein are the second significant barriers to its application. There are many causes of unpleasant taste and flavour, which include lipid oxidation and lipoxygenase activities. The main volatile compounds in pea protein products connected with the off-flavour are pentanol, hexanol, heptanol, hexanal, and ethyl vinyl ketone (Wang et al., 1997). Several methods have attempted to reduce the most potent odor-active volatiles in pea protein preparations. Such as temperature controlling, cyclodextrins entrapping and flavour masking (Hashimoto, 2004; Suratman et al., 2004; Lan et al., 2019). Except for these physical and chemical methods, the reduction of beany flavour can also be achieved by lactic acid bacteria (LAB) fermentation.

LAB fermentation has been used since ancient times to preserve perishable food materials (McGovern, 2013). Fermentation is the process of converting carbohydrates to alcohol or organic acids using microorganisms. Widely consumed fermented foods include yoghurt, vinegar, olives, and cheese. More foods prepared by fermentation may also be based on beans,

grain, vegetables, fruit, honey, dairy products, fish, meat, or tea (Gupta & Abu-Ghannam, 2012). With respect to reduction of the beany flavour by fermentation, many researchers agree that technology could remove or reduce the off-flavour of legume protein (Moy, Lu, & Chou, 2012; Schindler et al., 2012), which is commonly attributed to change or decrease of volatile compounds in extracted protein (Kaneko, Kumazawa, & Nishimura, 2011; Shi et al., 2015). During the fermentation, complex organic compounds are broken down into smaller molecules by lactic acid microorganisms (Schindler et al., 2012). Lactic acid bacteria that ferment food comprise of a large number of species as such as *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. bulgaricus, *Lactobacillus acidophilus*, and *Lactobacillus helveticus*. Probitioc bacteria such the *Bifidobacterium* sp. also participate in lactic fermentation, although their growth is slow. Therefore, lactic acid fermentation has been widely used in various pea seeds and pea protein modification to improve the sensory and functional properties of the final products (Marilley et al., 2004; Moslehishad et al., 2013; Czarnecka et al., 1998).

The low solubility, especially insolubility at low pH is another problem associated with the application of pea protein in fermented food. Coconut milk has a rich and creamy texture (Belewu & Belewu, 2007), and when pea protein and coconut milk are mixed, the pea protein particles can be wrapped in the fat granules of the coconut milk and thus become suspended in the solution. The fermentation of pea protein and coconut milk mixture will increase the solubility of the pea protein at low pH and produce a more uniform texture for the fermented pea protein-coconut milk beverage. Furthermore, coconut milk has a very aromatic smell which could help to mask and reduce the beany flavour of the pea protein.

## 1.2 Aim and Objectives

**Aim:**

The main aim of this project was to reduce the yellowness and reduce the beany flavour of the commercial pea protein powder for the production of a new fermented pea protein-coconut milk beverage.

**Objectives:**

1. To improve the colour and beany flavour of commercial pea protein powder using isoelectric precipitation and salt extraction methods;
2. To use orthogonal data analysis to optimise fermentation conditions of pea protein-coconut milk fermentation;
3. To produce a stable prototype fermented pea protein-coconut milk beverage through evaluating the physicochemical and sensory properties.

# 2. LITERATURE REVIEW

## 2.1 Introduction

Over the last two decades, there has been an increasing demand for healthy and protein-rich foods (Chacón-Lee & González-Mariño, 2010; Abdel-Rahman, Eltayeb, Azza, & Feria, 2011), as protein is an important nutrient required for the healthy growth and functioning of the human body. There have two kinds of protein sources, animal and plant. Animal protein sources are considered to be complete sources of protein because they contain all of the essential amino acids that your body needs to function effectively. In contrast, plant protein sources are considered to be incomplete, as they lack one or more of the essential amino acids that your body needs (Hoffman & Falvo, 2004). Therefore, to achieve a balanced amino acid intake, consumption of a variety of plant protein sources is required, so that the amino acid compositions complement each other in the diet. However, there is increasing evidence that a diet primarily based on animal protein is associated with various diseases in humans such as high blood pressure and heart diseases (Kaluza, Åkesson, & Wolk, 2015; Choi et al., 2013), mostly due to the high-fat content of animal protein. On the other hand, plant protein sources are generally good sources of dietary fibre and low in fat content, particularly saturated fats. Diets high in plant proteins, such as the vegetarian diet, are linked with many health benefits, with studies suggesting that vegetarians tend to have lower body weight, lower cholesterol and lower blood pressure levels than meat lovers. They also have a lower risk of stroke, cancer and death from heart disease than non-vegetarians (Craig, 2010). Therefore, plant-based represents a respectable dietary substitution to animal-based protein and it has much more health benefits for people than animal protein (Duranti & Gius, 1997; Kate, 2011).

Legumes (soybeans, peas and lentils) are widely known as important sources of food and feed proteins around the world (Weisse et al., 2009). Because of the high protein quantity of legume, and the benefits of consumption legume protein isolate have a great number of references (Duranti, 2006; Nunes, Raymundo, & Sousa, 2006; Duranti & Gius, 1997; Anderson et al., 1999; Rebello, Greenway, & Finley, 2014). It is recognized that the legume protein isolate offers the immense possibility in the development of a new class of plant protein food.

## 2.2 The pea and pea protein

### 2.2.1 Pea

Pea (*Pisum sativum*) is an herbaceous vine that belongs to the family of Fabaceae with common names, including English peas, sweet peas, and garden peas (Uebersax & Ruengsakulrash, 1989). *Pisum* is one of the oldest domesticated plants in the world. Carbonized pea seeds found in Neolithic settlements in Iraq, Turkey, and Greece (7000–6000 B.C.) have been attributed to domesticated peas, which indicates that peas have been cultivated for as long as barley and wheat (Zohary & Hopf, 1973). Besides soy, peanut, and bean, field peas constitute a significant sector of agricultural grain production, with approximately 25 million hectares grown annually worldwide (Vankosky et al., 2011).

Peas thrive in well-drained, sandy soil supplemented with adequate moisture. The seed can be planted at 10 °C, however, it grows faster at temperatures of 13 to 18 °C. Many cultivars reach maturity around 60 days after planting (Maiti et al., 2012) with each pod measuring about 5-8 cm in length and filled with smooth edible seeds (Figure 2.1). Peas are also grown to improve soil fertility as they can fix nitrogen into the soil through their roots, reducing the requirement for chemical fertilisers（Chapagain & Riseman, 2014).

a  b 

Figure 2.1 The plant (a) and seeds (b) of pea (*Pisum sativum)*

Note: Source of the figures-Google image

#### 2.2.1.1 Pea species

There are six species of pea seeds. Figure 2.2 describes the characteristics of pea plants. Peas have been grown in New Zealand since the beginning of arable farming, and are the third most important annual cash crop in New Zealand. Canterbury is the most popular area for pea growing, with Hawkes Bay also being a major producer of vining peas (White, 1983).

| Common name | Process peas, vegetable peas, edible podded peas |
|---|---|
| Grain characteristics | Wrinkled green cotyledoned grain with a clear – green seed coat. |
| Maturity range | Early (9 nodes to first flower) to 17 nodes. |
| Leaf characteristic | Mix of leafed and semi-leafless varieties available. |
| Typical sowing window | Large range from late July through to early December. |
| Typical end use | Freezing, dehydration, canning, fresh vegetable solid as unthreshed pods, low fibre and large podded varieties (eg snow peas) consumed frozen and fresh. |
| Domestic and/ or export | Mix of export and domestic use. |
| Organic production possible? | Yes. |
| Major varieties | Ashton, Bolero, CFR Sonata, CFR Pinacle. |

| Common name | Green/blue field peas |
|---|---|
| Grain characteristics | Smooth/spherical blue-green cotyledoned grain with a transparent seed coat. |
| Maturity range | Usually mid-season, flowering around 15-17 nodes. |
| Leaf characteristic | Almost exclusively semi-leafless plant types. |
| Typical sowing window | September to end of October. |
| Typical end use | Split peas for soup, canning, whole seed and extruded snack production, rolling. |
| Domestic and/ or export | Majority exported for food use. |
| Organic production possible? | Yes. |
| Major varieties | Aragorn, Ariel, Crusader, Prussian Blue. |

| Common name | White/yellow field peas |
|---|---|
| Grain characteristics | Smooth – slightly wrinkled yellow cotyledoned grain with a transparent seed coat. |
| Maturity range | Mid-season maturity with node to first flower from 15-17 nodes. |
| Leaf characteristic | Apart from Komet, all are semi-leafless. |
| Typical sowing window | September to end of October. |
| Typical end use | Food use for split peas for soup, canning, extruded snack products, pea flour, animal feed. |
| Domestic and/ or export | Majority are exported. |
| Organic production possible? | Yes. |
| Major varieties | Alezan, Komet, Miami, Santana. |

| Common name | Maple field peas |
|---|---|
| Grain characteristics | Irregular/dimpled brown mottled grain with a yellow cotyledon. |
| Maturity range | Mid-late maturity with first flowering node usually from 16-18 nodes. |
| Leaf characteristic | Both tall indeterminate varieties (eg Whero) and shorter, more determinate forms (eg Courier). |
| Typical sowing window | August to end of October. |
| Typical end use | Predominantly used for bird feed industry. Undesirable for animal feed due to high tannin and anti-nutritional compounds such as trypsin inhibitor. Used also for food sprouts. |
| Domestic and/ or export | Almost exclusively exported. |
| Organic production possible? | Yes. |
| Major varieties | Courier, Whero. |

| Common name | Marrowfat field peas |
|---|---|
| Grain characteristics | Large, irregular, grain with green cotyledon and clear seed coat. |
| Maturity range | Mid season maturity with first flower around 15-16 nodes. |
| Leaf characteristic | Generally marrowfat varieties are short and leafed although new semi-leafless varieties are becoming popular. |
| Typical sowing window | September to end of October. |
| Typical end use | Food use in high value snack production in Japan and S.E. Asia. Premiums are paid for high quality colour, and uniform large grain. |
| Domestic and/ or export | Almost exclusively exported. |
| Organic production possible? | Yes. |
| Major varieties | Midichi, Midlea, Primo. |

| Common name | Forage peas |
|---|---|
| Grain characteristics | Medium sized tan/ brown or green coloured grain with a yellow or green cotyledon. |
| Maturity range | Usually late and indeterminate maturity to synchronise with cereal maturity. |
| Leaf characteristic | Both leafed and semi-leafless varieties available. Varieties are tall and highly productive in relation to dry matter with a low grain harvest index. |
| Typical sowing window | May to end of October. |
| Typical end use | Forage use: can be grown as a stand alone forage or silage crop or in combinations with cereals. |
| Domestic and/ or export | Domestic use. |
| Organic production possible? | Yes. |
| Major varieties | AP2, Magnus, Provider. |

Figure 2.2 Different types of peas and their characteristics (Greenwood, Aves, & Catherwood, 2008).

2.2.1.2 Nutritional value of the pea

Peas are an excellent source of a variety of health-promoting nutrients，such as vitamins, minerals, carbohydrates, proteins and soluble and insoluble fibre (Rubio et al., 2014).

2.2.1.2.1 Vitamins

Peas are important sources of vitamins, including Vitamin-C, Vitamin-A, Vitamin-K and Vitamin-B (Duranti & Gius, 1997) (Table 2.1). Consumption of natural vegetables /fruits rich in these vitamins has many benefits for the human body. Vitamin-C can scavenge harmful, pro-inflammatory free radicals from the body and help improve resistance against infectious agents (Jacob & Sotoudeh, 2002). Vitamin-A helps to protect from oral cavity and lung cancers (Stephensen, 2001). Vitamin-K can restrict neuronal damage in the brain, and hence it has an established role in the relief of Alzheimer's disease (Olson, 1984). Vitamin B6 consumption before pregnancy helps prevent neural tube defects in the foetus (Ogawa et al.,1991).

Table 2.1 Vitamin content of pea protein

| Vitamin | Concentration /100 g pea protein | Proportion of daily recommended intake (%) | Reference |
|---|---|---|---|
| Vitamin-C | 40 mg | 60 | Alonso et al., 2000 |
| Vitamin-A | 25.5 mg | 4 | Alonso et al., 2000 |
| Vitamin-K | 24.8 µg | 3 | Makhlouf et al., 1995 |
| Vitamin-B6 | 65 µg | 5 | Igbasan & Guenter, 1996 |

2.2.1.2.2 Minerals

Peas contain several important minerals, including calcium, iron, zinc, magnesium, copper, phosphorus, manganese and potassium. Of these, the most abundant is manganese. 100-g pea could supply a person with 12% of the recommended daily intake manganese. Consumption of 100-g of peas can also supply 5% phosphorus, 11% iron and 6% magnesium of the recommended daily intake (Makhlouf et al., 1995).

2.2.1.2.3 Fibre, carbohydrates, fat and other nutritional factors

Peas are good sources of fibre. Consumption of 100 g of peas can provide 10% of the recommended dietary fibre intake. Peas are predominantly carbohydrate, and 100 g pea contains 171.5 kJ, of which 125.5 calories comes from carbohydrate, 40 calories from protein and 6 calories from fat. The form of fat is omega-3 and omega-6 fatty acids (Alonso et al., 2000).

Peas also contain phytosterols, especially ß-sitosterol. Makhlouf et al. (1995) reported that vegetables such as legumes and cereals, which are rich in plant sterols can help reduce cholesterol levels in the human body. Fresh peas also contain antioxidant flavonoids such as carotenes, lutein, and zeaxanthin (Igbasan & Guenter, 1996).

### 2.2.2 Pea protein

Pea protein is an important protein in leguminous plants due to its high protein content. The protein content of commonly grown pea cultivars ranges from 22% to 32% per 100 g, making it a significant protein source in human and animal nutrition (White, 1983). Protein concentrates and isolates have been commercially produced from dried peas for over 50 years (Owusu-Ansah & McCurdy, 1991). The main pea protein is globulin, which has minimal solubility at its isoelectric point region (pH 4.0~6.0) (Barac et al., 2010). The solubility of pea protein increases rapidly under neutral, alkaline or extreme acidity. The maximum solubility of close to 80% was observed in the pH range 8-9 (Fernández-Quintela et al., 1997). The denaturation temperatures of pea globulin vicilin (7 S) and pea globulin (11 S) have been reported as 83 °C and 92 °C, respectively (Barac et al., 2015).

2.2.2.1 Nutritional characteristics of pea protein

Unlike some plant-based protein powders, pea protein is hypoallergenic, highly bioavailable and well-digested (Schaafsma, 2000).

2.2.2.1.1 Well-balanced amino acid

Pea protein is valuable for human nutrition due to its well-balanced amino acid profile (Table 2.2), which is similar to soy. It is a "complete protein" containing all nine essential amino acids for humans (Tömösközi et al., 2001) and it is rich in branched-chain amino acids (BCAAs) (Tömösközi et al., 2001). When used as a supplement in food manufacturing, pea protein has the advantage of having lower allergenicity compared to soy and whey (Campos-Vega, Loarca-Piña, & Oomah, 2010).

Table 2.2 The nutritional characteristics of pea protein

| Component | Parameter | Unit | per 100 g |
|---|---|---|---|
| Energy | Energy | kcal | 364 |
| Proximate composition | Protein | g | 72.73 |
| | Total lipid (fat) | g | 6.06 |
| | Carbohydrate, by difference | g | 3.03 |
| Minerals | Calcium, Ca | mg | 61 |
| | Iron, Fe | mg | 19.09 |
| | Sodium, Na | mg | 1000 |
| Amino acids | Tryptophan | g | 0.639 |
| | Threonine | g | 2.836 |
| | Isoleucine | g | 6.088 |
| | Lysine | g | 5.448 |
| | Methionine | g | 0.639 |
| | Cystine | g | 1.085 |
| | Phenylalanine | g | 4.006 |
| | Tyrosine | g | 2.712 |
| | Valine | g | 3.585 |
| | Arginine | g | 6.152 |
| | Histidine | g | 1.788 |
| | Alanine | g | 2.952 |
| | Aspartic acid | g | 8.552 |
| | Glutamic acid | g | 12.988 |
| | Glycine | g | 2.988 |
| | Proline | g | 3.158 |
| | Serine | g | 3.782 |

**Source:** USDA Research Service Branded Food Products Database, Report: 45333760 (2018)

Pea protein is one of the richest dietary sources of lysine (82 g /kg protein) (Vermeirssen et al., 2003). Lysine is essential for building connective tissue such as skin, cartilage and bones and has been shown to help the absorption of calcium (Unni et al., 2012). Lysine has also been reported can reduce anxiety and help balance blood glucose (Smriga et al., 2004). Additionally, the pea protein contains more than three times the

amount of arginine per gram than whey protein (Weihai, 2017). Arginine (L-arginine) plays a key role in muscle growth, assisting in protein synthesis and increasing blood flow to muscles.

#### 2.2.2.1.2 Hypoallergenic properties of pea protein

Pea protein is free of lactose, gluten, soy and nuts. It is naturally vegan and suitable for people with food allergies or with restricted dietary requirements (Swagerty, Walling, & Klein, 2002). Due to the lack of lactase, nearly two-thirds of the adult population in the world has some difficulty in digesting lactose (Vesa, Marteau, & Korpela, 2000). Gluten intolerance is the adverse reaction to gluten present in wheat, barley and rye. It is another common problem. The most severe symptom of intolerance to gluten is celiac disease (Jacob & Sotoudeh, 2002). Pea protein has the potential to help to alleviate the intolerance problems.

### 2.2.2.2 Isolation of pea protein

There are three forms of pea protein comprising of pea flour, pea protein concentration and pea protein isolate (Tömösközi et al., 2001). The average protein, starch and fat composition of pea flour, concentrate and isolate are shown in Table 2.3. Pea flour is made by the dehulling of the peas and grind it into powder. Pea protein concentrate can be prepared by corrosive filtration of the pea. The protein isolate is processed by wet preparation (dissolving the proteins in water, acid, or alkali) which increases protein content from 48% to 90% (Owusu-Ansah & McCurdy, 1991).

Table 2.3 The average composition of pea flour, concentrate and isolate (O'Kane, 2004)

| Composition | Whole seed /Flour (%) | Concentrate (%) | Isolate (%) |
|---|---|---|---|
| Protein | 25 | 50 | 85 |
| Starch | 50 | 17 | 0 |
| Fat | 5-6 | 4 | <3 |

The main method used for the preparation of pea protein isolate involves the precipitation of the protein by isoelectric precipitation, followed by centrifugation and collection. First, the peas are ground into powder, followed by dissolving the proteins in water, acid, or alkali and then centrifuged to expel the insoluble materials. The precipitated protein curd is further centrifuged or sieved. The precipitate or curd is dried to produce protein isolate (Morita &

Kiriyama, 1993). The protein isolate can be also prepared by "salt extraction", "hydrophobication", and ultrafiltration (Murray, Pizzorno, & Pizzorno, 2005). Figure 2.3 shows a schematic process of the isoelectric precipitation process for the production of pea protein isolates (Boye, Zare, & Pletch, 2010).

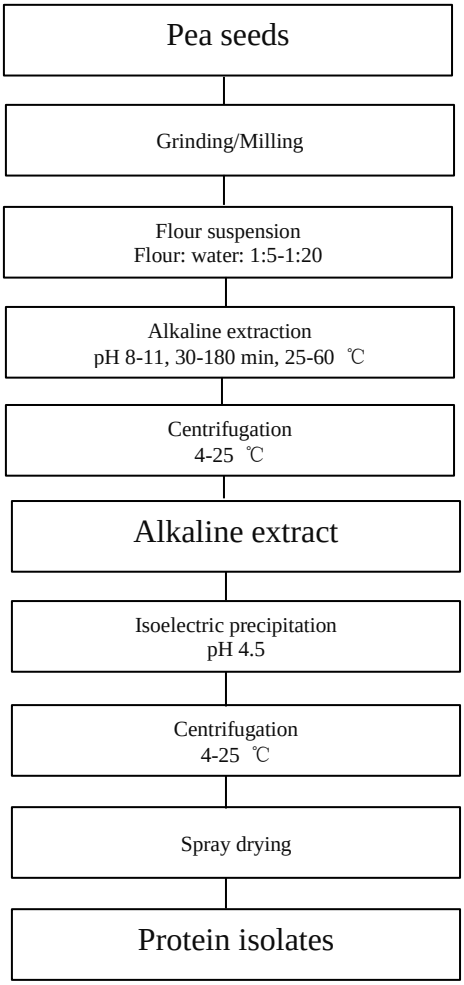



Figure 2.3 Isoelectric precipitation process for the production of pea protein isolates (Boye, Zare, & Pletch, 2010)

Several factors affect the yield of protein isolate from the isoelectric precipitation method such as powder particle size, solubilizing medium and the pH of solubilisation (Nielsen, Petersen, & Dambmann, 2001). According to Scopes (2013), the best average particle size for this method is between 100 µm to 150 µm for protein solubilisation. Larger particle sizes lead to a lower protein yield. A similar yield is obtained when using potassium hydroxide and sodium hydroxide as the solubilising protein medium. However, when calcium hydroxide is used as the solubilizing medium, less than 10% pea protein dissolves because of the salting-out effect

of calcium ions (Arai, Nojiri, & Naito, 1998). Acids are also commonly used for solubilization, except for sulphuric acid, this is possibly due to the effect of precipitating of the sulfate ion lower than other acids. (Gueguen, 1980). The pH of the solubilizing and precipitating agents is another factor that affects the composition of the isolate. At less than pH 5.3, the protein isolate will have lower protein content and higher lipid content than at or above pH 5.3 (Fredrikson et al., 2001).

Salt extraction takes advantage of the salting-in and salting-out phenomena of proteins, followed by a desalting process to lower the ionic strength of the protein environment (Boye, Zare, & Pletch, 2010). Briefly, flour is stirred for 10–60 minutes in a salt solution of specified ionic strength at a 1:10 (w /v) ratio, followed by the removal of the insoluble matter by settling, decanting, screening, filtering, or centrifuging. The supernatant is then desalted and dried (Gueguen & Barbot, 1988). This method of salt extraction is convenient and straightforward and can be used for crude extraction and concentration of proteins. However, the protein concentration purified by salting out is lower and needs to be combined with other methods to gain high concentration refined protein (Murray, Pizzorno, & Pizzorno, 2005).

#### 2.2.2.3 Health benefits of pea protein

Pea protein is almost as good as whey protein for building muscle and recovering after workouts (Tang et al., 2009). This leguminous protein can also help reduce blood pressure and decrease the risk of diabetes (Paddock, 2009).

Pea protein is rich in branched-chain amino acids (BCAAs) which build muscle (Schaafsma, 2000). BCAAs stimulate protein synthesis and account for more than 35% of muscle mass, and therefore, are ideal choices to rebuild and recover muscles after work-out.

Another advantage of pea protein is that it does not contain starch and fiber which can cause undesirable effects such as gas and bloating (Weigle et al., 2005). Pea protein is more comfortable on the stomach than dairy-based protein due to its highly digestible (94%) (Le Guen, 1995).

Pea protein does not raise blood sugar levels as do fruit juices or other high-carbohydrate foods due to the low concentration of sugar in peas. Besides, pea protein can assist the body in

spending more time digesting low glycemic food which can help to keep blood sugar even (Monro & Shaw, 2008). Low glycemic food will also slow down the rate of stomach emptying and keep a feeling of fullness for longer. Therefore, pea protein can help to maintain healthy body weight and avoid the risks associated with obesity and diabetes (Mollard et al., 2014).

#### 2.2.2.4 Disadvantages of pea protein

Even though pea protein has many advantages, most products containing pea protein have a green colour and a bitter taste, making them mostly unacceptable to the customers. Also, pea protein has a lower solubility than dairy ingredients. Pea protein exhibits poor solubility in the low pH beverages, such as kefir and yogurt, even though it at low concentrations. Therefore, the applications of pea protein are low. Hence there is increased research interest in reducing the bitter flavour in pea ingredients and products. (Dahl, Foster, & Tyler, 2012).

#### 2.2.2.5 Applications of pea protein

Pea protein can be found in a variety of products, from protein powders to meat to yogurt (Table 2.10). Based on the production procedures, pea protein can be divided into three groups: concentrates, with lower protein content which may contain some fat and carbohydrates; textured, which can be used as meat replacements; and isolates, which have the highest protein concentration (Campos-Vega, Loarca-Piña, & Oomah, 2010).

Between 2010 and 2014, four new types of products based on pea protein were produced: processed meat, fish, baked goods, snacks and desserts (Babault et al., 2015). Besides, between 2013 and 2014, food and beverage product promotions featuring pea protein expanded by 49% (Frost and Sullivan, 2012). Although less than 5 % of all protein items produced in 2012 utilised pea protein, globally non-soy class legume-based proteins were used in 34% of issues, with pea protein being present in 55% of the items in that vegetable class. Pea protein no two soy-problem highlights: allergens and GMO (genetically modified organism), so it possibly became the remarkable advance driver for pea protein. Consumer concerns about soy allergies and genetically modified soybean have motivated research into plant-protein alternatives. According to the Grand View Research market analysis (Grand View Research, 2017), the global pea protein market is expected to reach $133.5 million in 2025, due to the high nutritional value and sustainability of the pea crop.

## 2.3 Beany flavour of pea protein

Beany flavour is an unpleasant flavour associated with pea products. Pea (*Pisum sativum*) as a source of high-quality protein presents economic and nutritional advantages for use in the animal and human food industry (Martinez et al., 2008). However, pea and pea proteins are not widely used in food applications because of their strong beany flavour (Klein & Raidl, 1986; Pattee et al., 1983). Undeniably, the application of pea as a healthful and low-cost source of protein for humans depends on the acceptance of consumers (Patil, 2017).

### 2.3.1 Volatile compounds contributing to the beany flavour

Numerous studies have attempted to identify and reduce the most potent odor-active volatiles in pea preparations (Jakobsen et al., 1998; Murray, Shipton & Whitfield, 1970; Murray et al., 1976). The volatiles of pea products include aldehydes, alcohols, ketones and furans (Kaneko, Kumazawa, & Nishimura, 2011; Shi et al., 2015; Suratman, Jeon, & Schmidt, 2004). A further study reported that typical beany flavour-causing compounds from pea products include pentanol, hexanol, heptanol, hexanal, and ethyl vinyl ketone (Wang et al., 1997). In the study of Suratman et al. (2004), hexanal was identified as the beany flavour-causing volatile compound that had the highest concentration among all the detected volatile chemicals in the studied pea protein. The similar high proportion of hexanal in the volatiles of raw pea was discovered by many studies (Yuan & Chang, 2007; Zhang, Guo, Liu, & Chang, 2012).

Table 2.4 shows the volatile compounds associated with beany flavour. The presence of hexanal has been reported in most published reports because it is considered one of the most important volatile compounds contributing to the beany flavour. However, many different compounds have been reported as beany flavour volatile compounds in published studies. This may imply that different researchers have dissimilar opinions on the chemical compounds that contribute to the beany flavour. It may also indicate that volatile compounds contributing to the beany flavour in one product may not be regarded as the major beany flavour compounds in another product.

Table 2.4 Beany flavour volatile compounds

| Volatile beany flavour compound | Reference |
|---|---|
| Hexanal | Kaneko et al. (2011); Shi et al. (2015); Yuan and Chang (2007); Lei and Boatright (2008); Schindler et al. (2012) |
| Hexanal | Kaneko et al. (2011); Shi et al. (2015); Yuan and Chang (2007); Lei and Boatright (2008); Schindler et al. (2012) |
| 1-Penten-3-ol | Suratman et al. (2004); Suratman et al. (2004); Yuan and Chang (2007) |
| 1-Penten-3-ol | Suratman et al. (2004); Suratman et al. (2004); Yuan and Chang (2007) |
| Hexanol | Shi et al. (2015); Yuan and Chang (2007) |
| Hexanol | Shi et al. (2015); Yuan and Chang (2007) |
| 1-Octen-3-one | Kaneko et al. (2011); Suratman et al. (2004); Schindler et al. (2012) |
| 1-Octen-3-one | Kaneko et al. (2011); Suratman et al. (2004); Schindler et al. (2012) |
| 1-Octen-3-ol | Kaneko et al. (2011); Shi et al. (2015); Schindler et al. (2012) |
| Trans, trans-2,4-decadienal | Shi et al. (2015); Yuan and Chang (2007) |
| Heptanal | Suratman et al. (2004) |
| n-Pentanal | Schindler et al. (2012) |
| 2-nonenal | Suratman et al. (2004) |
| (E, Z)-2,4-decadienal | Kaneko et al. (2011) |
| Trans-2-hexenal | Shi et al. (2015) |
| Trans-2-nonenal | Yuan and Chang (2007) |
| Benzaldehyde | Suratman et al. (2004) |
| n-Hexan-1-ol | Schindler et al. (2012) |
| Guaiacol | Schindler et al. (2012) |
| Nonanal | Suratman et al. (2004) |

### 2.3.2 Causes of beany flavour

Peas contain unsaturated lipids and beany flavours can be caused by lipid oxidation that occurs in the production of pea protein. Lipid oxidation can take place via both enzymatic and non-enzymatic routes which detailed in the next part (Sikorski & Kołakowska, 2010).

The basic mechanism of lipid oxidation is shown in Figure 2.4 ( Reineccius, 2006). The process is a radical reaction which includes three steps: initiation, propagation and termination. As seen in Figure 2.4 a lipid acid radical is formed from an unsaturated lipid in the initiation stage. Due to the instability of the lipid acid radical, it reacts with oxygen to generate a lipid peroxyl radical which is also unstable. Consequently, it reacts with another unsaturated lipid to create a lipid hydroperpoxide. This process recurs until an antioxidant stops it.

An enzyme is known as lipoxygenase (LOX) involved in the lipid oxidation of pea foods. The initiation stage of the LOX pathway is different from the basic lipid oxidation because molecular oxygen is involved in catalysing the reaction (Sikorski & Kołakowska, 2010). Unsaturated lipid acids react to produce unstable lipid hydroperoxides which can further decompose to a variety of carbonyls such as aldehydes. These carbonyl compounds can generate beany flavours in pea protein. Figure 2.5 shows the mechanism of the formation of volatile compounds by the lipid peroxidation process (Ayala, Muñoz, & Argüelles, 2014). After lipid hydroperoxides are formed, they further decompose to form alcohols, aldehydes, ketones and furans which also contribute to the beany flavour in pea protein.

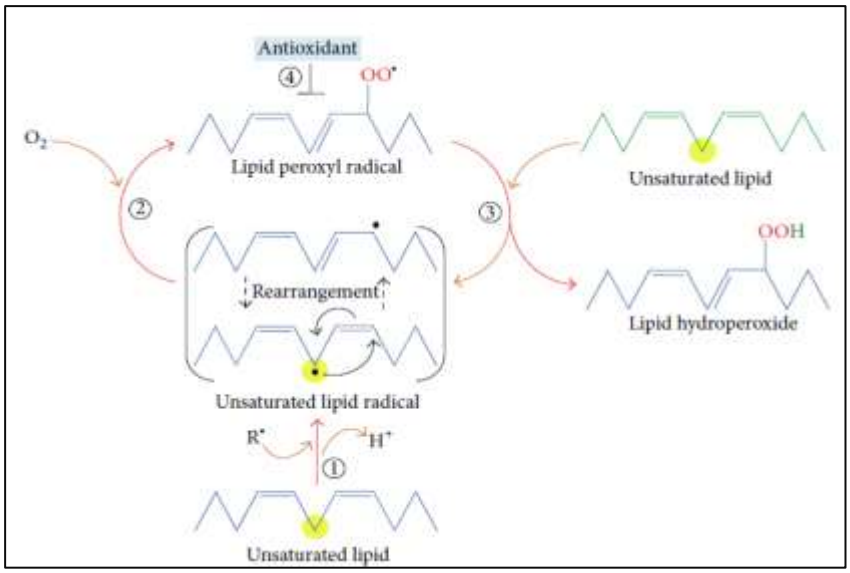
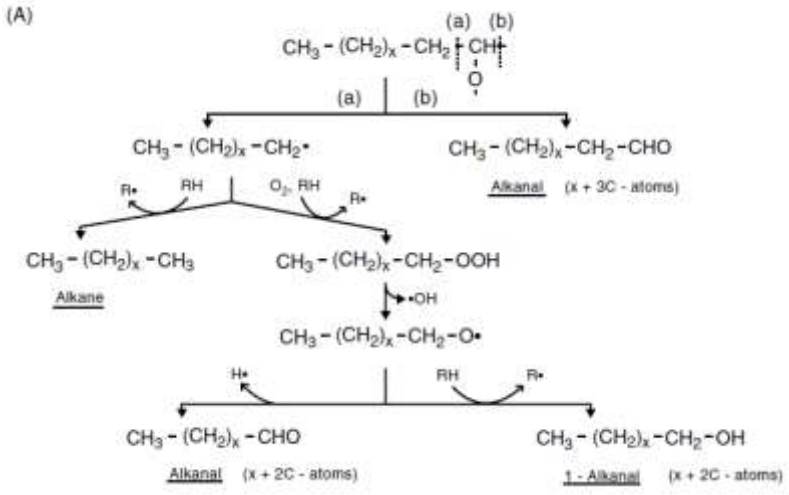



Figure 2.4 Formation of volatile compounds due to the breakdown of lipid hydroperoxides (Reineccius, 2006)



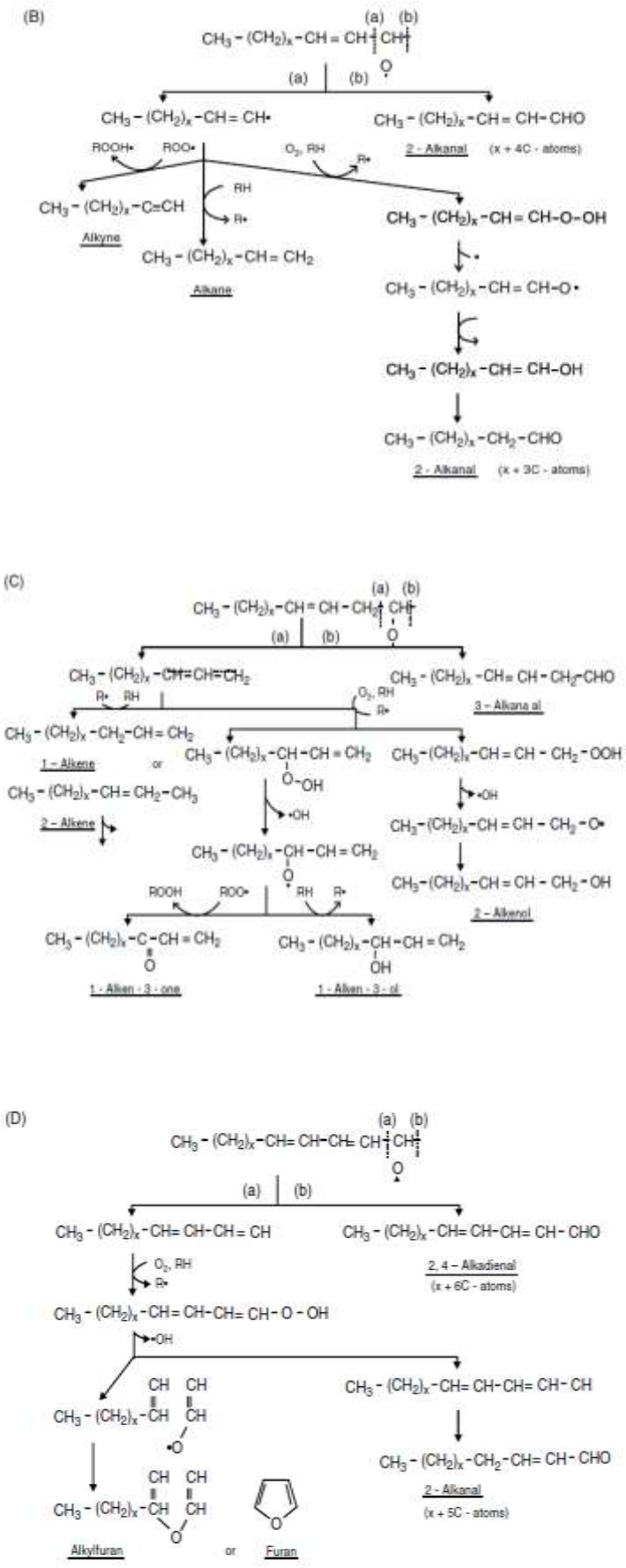



Figure 2.5 Lipid peroxidation process (Ayala, Muñoz, & Argüelles, 2014)

### 2.3.3 Reducing beany flavour in pea protein

Many methods have been reported to reduce the beany flavour of pea protein. Besides the physical, chemical and flavour masking methods, a reduction in beany flavour can also be achieved by fermentation.

#### 2.3.3.1 Physical method for reducing beany flavour in pea protein

Many treatments have been reported to improve the flavour of the pea products by inactivating LOX because LOX is essential to the reaction of lipid oxidation which decomposes to form beany flavour volatile chemicals (Wolf, 1975).

Hot grinding of pea protein is an effective heat treatment for reducing LOX activity (Lv et al., 2011). Table 2.5 summaries the beany flavour volatile compounds reported being reduced by hot grinding in different studies. Hot grinding significantly reduced the LOX activity of raw soymilk and markedly lowered the production levels of odour compounds such as hexanal, hexanol and 2-pentylfuran which cause beany flavours (Zhang et al., 2012). Similar results were observed by Mizutani and Hashimoto (2004) who showed that 80 ºC was an effective pea grinding temperature to reduce lipid hydroperoxide activity as well as beany flavour content from n-hexanal and 1-hexanol. Lv et al. (2011) reported that a grinding temperature of between 80 ºC and 100 ºC could effectively reduce beany flavour volatile compounds including n-hexanal, 1-hexanol and 1-octen-3-ol.

Table 2.5 Major beany flavour volatile compounds reduced by hot grinding

| Major beany flavour volatile compounds | Grinding temperature (ºC) | Reference |
|---|---|---|
| Hexanal<br>Hexanol<br>2-Pentylfuran<br>1-Octen-3-one<br>1-Octen-3-ol | 80.5 | Zhang et al. (2012) |
| n-Hexanal<br>1-Hexanol | 80 | Mizutani and Hashimoto (2004) |
| n-Hexanal<br>1-Hexanol<br>1-Octen-3-ol<br>Trans-2-hexenal<br>Trans, trans-2,4-decadienal | 80-100 | Lv et al. (2011) |

Besides hot grinding, ultra-high temperature (UHT) processing has been reported to be a successful method to reduce the beany flavour volatile compounds (Zhang et al., 2012). In theory, a higher temperature can accelerate the inactivation of LOX enzymes which can reduce the rate of lipid oxidation resulting in less beany flavour volatile chemicals.

Several studies used more than one heat treatment method to reduce the beany flavour, combining different heat treatment methods such as hot grinding and UHT processing (Mizutani & Hashimoto, 2004; Zhang et al., 2012; Kwok & Niranjan, 1995). The combination of different heat treatment methods appeared to be more effective in reducing beany flavours than a single treatment alone (Mizutani & Hashimoto, 2004).

#### 2.3.3.2 Chemical methods

In addition to physical methods, various chemical processes have been investigated for their ability to reduce beany flavour in pea protein. Chemicals such as cyclodextrins and antioxidants can be used to reduce the pea beany flavour compounds by removing them after their formation (Suratman et al., 2004). Antioxidants such as Vitamin E and Vitamin C were also investigated for their effects on reducing the beany flavour in soybean (Dahuja & Madaan, 2004).

#### 2.3.3.3 Flavour masking

Another solution to the undesirable beany flavour is masking or covering the beany flavour in pea products by the addition of flavours or other compounds. Beany flavours were reduced through the unfolding of the secondary structure of PPI by forming solid dispersions with gum arabic or maltodextrin during spray-drying (Lan et al., 2019). Also, beany flavour could be covered by blueberry flavour (Potter et al., 2007).

#### 2.3.3.4 Fermentation

The undesirable off-flavour of pea-based products has limited the consumption of the products and the application of pea protein. Fermentation has been a traditional option to overcome these limitations to produce acceptable products to the consumer (Rivera & Gallardo, 2010). The characteristic acceptable aroma and flavour of fermented pea protein foods are partially attributed to the metabolism of lactic acid bacteria (LAB) (Li et al., 2014).

Much of the current literature agrees that fermentation can reduce the beany flavour of legume protein (Blagden & Gilliland, 2005; Moy, Lu, and Chou, 2012; Schindler et al., 2012), and this is commonly attributed to the change or decrease of volatile compounds in the protein extract (Kaneko, Kumazawa, & Nishimura, 2011; Shi et al., 2015; Suratman, Jeon, & Schmidt, 2004). Hexanal is assumed to be the principal compound contributing to the beany flavour by many studies (Yuan & Chang, 2007; Zhang, Guo, Liu, & Chang, 2012).

The application of fermentation to remove the beany flavour has been reported in several studies (Table 2.6). Table 2.6 lists the major beany flavour volatile compounds reduced by fermentation. Blagden and Gilliland (2005) reported that both *Streptococcus thermophilus* and *Lactobacillus acidophilus* could completely remove hexanal which is considered a major beany flavour compound in soymilk. Other volatile compounds, such as methanol and acetaldehyde were also reduced compared to the control sample. This finding was supported by another study showing that the beany flavour volatile compounds n-hexanal and n-hexanol in pea protein extracts could be reduced by lactic acid bacteria (*Lactobacillus plantarum* and *Pediococcus pentosaceus*) fermentation indicating that fermentation could either reduce the generation of beany flavour or mask the unpleasant beany flavour (Schindler et al., 2012). Moy, Lu, and Chou (2012) also found that the hexanal content from the volatile compounds in tofu (tofu fermented by *Aspergillus oryzae*) was significantly reduced compared with that in non-fermented tofu. These studies provide clear evidence that fermentation may have a positive effect on improving the flavour of pea products by reducing or eliminating the beany flavour volatile compounds.

Table 2.6 Major beany flavour volatile compounds reduce by fermentation

| Major beany flavour volatile compounds reduced | Bacteria for fermentation | Products | Reference |
|---|---|---|---|
| Hexanal<br>Methanol<br>Acetaldehyde | *Streptococcus thermophilus* and *Lactobacillus acidophilus* | Pea milk | Blagden and Gilliland (2005) |
| n-Hexanal<br>n-Hexanol | *Lactobacillus plantarum* and *Pediococcus pentosaceus* | Pea Protein Extracts | Schindler et al. (2012) |
| n-Hexanal<br>Heptanal<br>Nonanal | *Aspergillus oryzae* | Sufu | Moy et al. (2012) |

## 2.4 Coconut milk

Coconut (*Cocos nucifera*), which belongs to the Palm family (*Arecaceae*), is grown in abundance in Malaysia, Polynesia and southern Asia. Coconut milk is a white, milky substance extracted from the white flesh inside the mature brown coconut (Figure 2.6). Coconut milk has a rich, creamy texture, and it is used in many traditional cuisines around the world (Belewu & Belewu, 2007). The use of the fruit often depends on its processing technique, or specifically the method of squeezing and thinning the coconut cream. Thicker products are mostly used for rich desserts, while thinner milk is used for soups and curries, and the thin, fluid milk is mostly used as a dairy-free milk substitute (Seow & Gwee, 1997).

a  b 

Figure 2.6 The image of coconut (a) and coconut milk (b).

Note: Source of the figures-Google image

### 2.4.1 Nutritional characteristics of coconut milk

Coconut milk contains high levels of saturated fat, making it a very high-calorie food. About 93% of its calories come from fat, including saturated fats (Pehowich, Gomes, & Barnes, 2000). Coconut milk is also rich in vitamins and minerals, although the nutritional content often differs by product (Papamandjaris, 1999). For example, coconut milk drinks, have a different nutritional profile to canned coconut milk. The carbohydrate, fat and protein content of 240g raw coconut milk and canned coconut milk are 13.3 g, 57.2 g, 5.5 g and 6.8 g, 51 g, 4.8 g, respectively (Seow & Gwee, 1997).

### 2.4.2 Healthy benefits of coconut milk

Previous studies suggest that coconut milk confers numerous health benefits such as stimulating weight loss (Dayrit, 2015), improving heart health (Khaw et al., 2018) and enhancing the immune system (Lappano et al., 2017).

Coconut milk contains medium-chain triglycerides (MCTs), which researchers have linked with increase metabolism, benefits body composition and help you lose belly fat (Dayrit, 2015). Coconut milk can significantly increase levels of high-density lipoprotein cholesterol (HDL), which protects the heart and removes low-density lipoprotein cholesterol (LDL) from the blood (Khaw et al., 2018). Coconuts contain significant amounts of fat, but unlike other nuts, they provide fat that is mostly in the form of medium chain saturated fatty acids (MCFAs) in particular, one called lauric acid (Dayrit, 2015). Lauric acid is converted in the body into a highly beneficial compound called monolaurin. Monolaurin is an antibacterial agent, an antiviral and antifungal, used to treat viral infections, including influenza (Elmore et al., 2014). It ultimately can boost the immune system and further fight against bacteria and yeasts. Therefore, it thought that consumption of coconut milk and other coconut-derived foods may help protect the body from infections and viruses (Lappano et al., 2017). Due to these benefits, coconut milk has gained popularity in the healthcare industry as an alternative to dairy milk.

## 2.5 Lactic acid bacteria

Lactic acid bacteria (LAB) are gram-positive, non-spore forming cocci, coccobacilli or rods. Although many genera of bacteria produce lactic acid as a primary or secondary end-product of fermentation, the term lactic acid bacteria are conventionally reserved for the order *Lactobacillales*, which includes *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *Lactococcus* and *Streptococcus* (Klaenhammer, 1993).

LAB ferment glucose primarily to lactic acid, or to lactic acid, $CO_2$ and ethanol. Most of LAB grow anaerobically, but unlike most anaerobes, they grow in the presence of oxygen as "aerotolerant anaerobes". Although they lack catalase, LAB has superoxide dismutase and have alternative means to detoxify peroxide radicals, generally through peroxidase enzymes (Makarova et al., 2006).

Since LAB obtain energy only from the metabolism of sugars, they are restricted to environments in which sugars are present (Carr, Chill, & Maida, 2002). The microorganisms have limited biosynthetic ability, having evolved in environments that are rich in amino acids, vitamins, purines and pyrimidines, so they must be cultivated in complex media that fulfill all their nutritional requirements (Axelsson, 2004). Most of LAB are free-living or live in beneficial or harmless associations with animals and are commonly found in milk, milk products and decaying plant materials. In humans, they are normal flora of the oral cavity, the intestinal tract and the vagina, where they play a beneficial role in maintaining human health (Naidu, Bidlack, & Clemens, 1999).

Lactic acid bacteria are among the most important groups of microorganisms used in food fermentations performing an essential role in the preservation and production of wholesome foods (Carr, Chill, & Maida, 2002). LAB microorganisms contribute to the taste and texture of fermented products and inhibit food spoilage bacteria by producing growth-inhibiting substances and large amounts of lactic acid (Leroy & De Vuyst, 2004). LAB is used in the manufacture of dairy products such as acidophilus milk, yogurt, buttermilk, sour cream, and cheeses. LAB is also important commercially in the processing of meats (sausage, cured hams), alcoholic beverages (beer, wine), and vegetables (kimchi and sauerkraut) (Axelsson, 2004).

### 2.5.1 The application of lactic acid bacteria

Common lactic acid bacteria used as starter cultures include species of *Lactobacillus* (*Lactobacillus acidophilus*, *L. plantarum*, *L. reuteri*, *L. johnsonii*, *L. rhamnosus*, *L. casei*) and *Bifidobacterium* species (*Bifidobacterium. lactis*, *B. breve*, and *B. longum*) (Wang et al., 2010). In the dairy industry, the integration of LAB strains in traditional food products has resulted in the production of novel fermented dairy products: such as yoghurt, kefir and probiotic beverage (Chiang & Pan, 2012, Liong, Easa, Lim, & Kang, 2009). Typical lactic acid bacteria used in fermented foods and beverages are shown in Table 2.7.

In addition to dairy products, lactic acid bacteria (LAB) are also broadly used in plant food fermentations. This process can improve the nutritional quality and health benefits of plant foods, which has generated scientific research. Since consumers treat edible peas as important food, fermenting peas and pea products with LAB can improve their biological activity and nutritional composition (Weinberg et al., 1993).

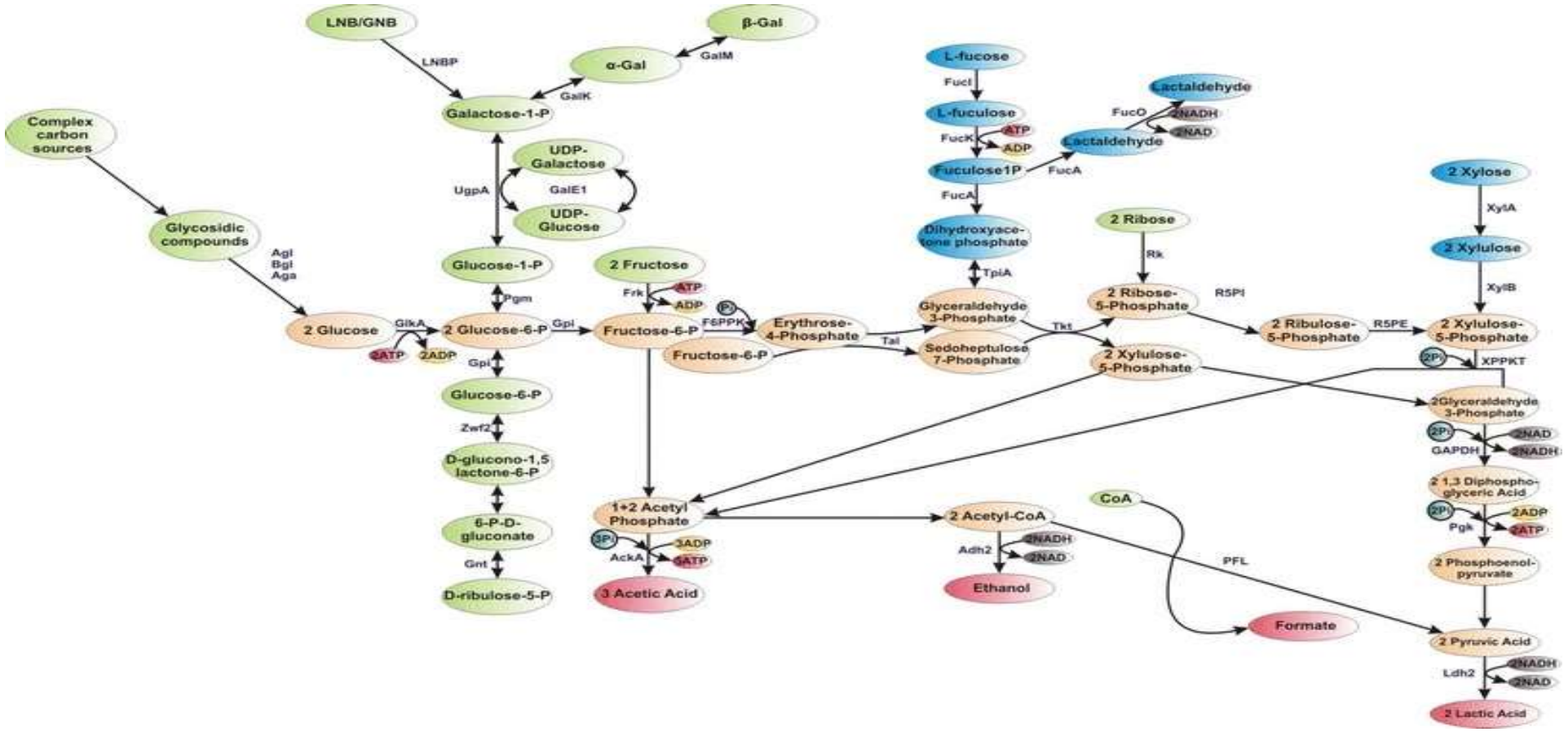
Table 2.7 Lactic acid bacteria used as starter cultures for pea source fermentation

| Pea source | Starter culture | Temperature (°C) | Time (h) | Reference |
|---|---|---|---|---|
| Dried seeds of green pea | *Lactobacillus casei* ATCC393, *Lb. zeae* LMG17315, *Lb. paracasei* BGHN14, *Lb. rhamnosus* BGT10, *Lb. plantarum* LMG9208, *Lb. plantarum* BGBUK2-5, *Lb.plantarum* PV2-45a, *Lb. plantarum* BGGA8, *Lb. plantarum* BGHO10. | 30 | 16 | Stanisavljević et al., 2015 |
| "Opal" pea | *Lactobacillus plantarum* | 30 | 18 | Czarnecka et al., 1998 |
| Cow milk and pea milk mixtures. (Pea protein isolate: Nutralys® S85F) | lyophilized S. *thermophilus*, *Lactobacillus bulgaricus*, *S. thermophilus* 102303T, *L. delbrueckii* subsp. *bulgaricus* 104365, *L. acidophilus* 76.13, *L. helveticus* CNRZ 303, *Lactobacillus casei* subsp. *casei* ATC 334, *Lactobacillus rhamnosus* CRBIP 24.130, *Lactobacillus fermentum* CRBIP 24.11 | 37 | 24 | Yousseef et al., 2016 |

Stanisavljević et al. (2015) selected nine LAB strains (Table 2.7) to test their ability to hydrolyse pea proteins and tested their ability to grow in pea seed protein-based media. Two strains, *Lactobacillus rhamnosus* BGT10 and *Lactobacillus zeae* LMG17315, displayed strong proteolytic activity for pea proteins and significantly increased the antioxidant activity of pea seed-based medium during fermentation. Yousseef et al. (2016) sellected five mixtures of milk and pea protein (Volum ratio: 100:0, 90:10, 80:20, 70:30, 60:40 respectively) and fermented them at 37 °C for 24 h by ten starter cultures (show in Table 2.7) of lactic acid bacteria ($10^7$ CFU /mL) to select the concoctions which can product yoghurt that similar to a conventional yoghurt. The result showed that two groups of products of 0 g or 10% pea protein seemed to be the most similar to traditional dairy products. The third group (20% pea protein) included products fermented with two starters: *Streptococcus thermophilus* and *Lactobacillus helveticus* with negative characteristics such as astringency and bitterness. four starter cultures: *Streptococcus thermophilus* + *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Streptococcus thermophilus* + *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Streptococcus thermophilus* + *Lactobacillus acidophilus* and *Streptococcus thermophilus* + *Lactobacillus casei* subsp. *casei* seem promising for the fermentation of milk and pea protein mixtures.

### 2.5.2 *Bifidobacterium*

Non-motile *bifidobacteria* with variable morphology are anaerobic gram-positive bacteria. They are a major (92%) group of gastrointestinal tract microbiota of mammals. *Bifidobacterium* degrades carbohydrates through a particular fructose-6-phosphate phosphoketolase pathway, known as the "bifid shunt" (De Vuyst et al., 2014), where the fructose-6-phosphoketolase enzyme (EC 4.1.2.2) plays a key role **(**Figure 2.7) (Killer et al., 2010). Additional enzymes are needed to channel various diet- and host-derived carbon sources into the bifid shunt (Figure 2.7), which allows *bifidobacteria* to produce more energy in the form of ATP from carbohydrates than the fermentative pathways (Davidson & Chen, 2004).




Notes: *AckA*, Acetate kinase; *Adh2*, aldehyde-alcohol dehydrogenase 2; *Aga*, α-galactosidase; *Agl*, α-glucosidase; *AraA*, l-arabinose isomerase; *AraB*, Ribulokinase; *AtsA*, sulfatase; *Bgl*, β-glucosidsae; *Eno*, enolase; *GalE1*, UDP-glucose 4-epimerase; *GalA*, β-endogalactanase; *GalG*, β-galactosidase; *GalK*, galactokinase; *GalM*, glactosemutarotase; *GAPDH*, glyceraldehyde-3-phosphate dehydrogenase; *GlkA*, glucokinase; *Gpi*, glucose 6-phosphate isomerase; *Gpm*, phosphoglycerate mutase; *FrK*, frucktokinase; F6PPK, fructose-6-phosphoketolase; *FucI*, l-fucose isomerase; *FucK*, l-fuculose kinase; *FucA*, l-fuculose-1-phosphate aldose; *FucO*, lactaldehyde reductase; *Ldh2*, lactate dehydrogenase; *LNBP*, lacto-*N*-biose phosphorylase; *NagA*, *N*-acetylglucosamine-6-phosphate deacetylase; *NagB*, glucosamine-6-phosphate deaminase; *NagK*, *N*-acetylglucosamine kinase; *NahK*, *N*-acetylhexosamine kinase; *NanA*, *N*-acetylneuraminatelyase; *NanEPgk*, phosphoglyceric kinase; *NanK*, *N*-acetylmannosamine kinase; *Pgm*, phosphoglucomutase; *Pfl*, formate acetyltransferase; *Pi*, phosphate; *Pyk*, pyruvate kinase; *Rk*, ribokinase; *R5PI*, ribose-5-phosphate isomerase; *R5PE*, ribulose-5-phosphate epimerase; Tal, transaldase; *Tkt*, transketolase; *UgpA*, UTP-glucose-1-phosphate uridylyltransferase; *XylA*, xylose isomerase; *XylB*, xylulose kinase

Figure 2.7 The fructose-6-phosphate phosphoketolase pathway in bifidobacterial (Pokusaeva, Fitzgerald & van Sinderen, 2011).

The metabolism of *bifidobacteria* has focused on oligosaccharide (metabolism), as these carbohydrates are available in their nutrient-limited environments. These are generally classified as plant-derived fructo-oligosaccharides or dairy-derived galacto-oligosaccharides (Mayo & Van Sinderen, 2010). Typical examples of the sugars are ribose, galactose, fructose, glucose, sucrose, maltose, melibiose and raffinose.

### 2.5.3 Plant-based fermented beverages

Due to the health-promoting properties of plant-fermented foods and beverages, these products are becoming increasingly popular among producers and consumers. The most popular and commercial plant-based fermented beverages are fermented tea, plant-based kefir and soybean yogurt (Table 2.8).

Table 2.8 Typical commercial fermented products (Ray & Joshi, 2014)

| Product | Country | Microorganism(s) | Substrate |
|---|---|---|---|
| Bread | International | *Saccharomyces cerevisiae*, other yeasts, lactic acid bacteria (LAB) | Wheat, rye, other grains |
| Cheese | International | LAB (*Lactobacillus lactis, Streptococcus thermophilus, Lb. shermanii, Lb. bulgaricus*), *Propionibacterium shermanii*, sometimes moulds (*Penicillium* spp.) | Milk |
| Fufu | West Africa | LAB, *Citrobacter freundii*, *Geotrichum* sp., *Candida* sp. and *Saccharomyces* sp. | Cassava root |
| Gari | West Africa | *Corynebacterium manihot*, yeasts, LAB (*Lb. plantarum, Streptococcus* spp.) | Cassava root |
| Idli | Southern India | LAB (*Leuconostoc mesenteroides, Enterococcus faecalis*), *Torulopsis, Candida*, *Trichosporon pullulans* | Rice and black gram |
| Kefir | North Africa | LAB | Milk |
| Kenkey | Ghana | LAB (*pediococcus cerevisiae, Leuconostoc mesenteroides,* and *Lc. fermentum*) | Maize |
| Kimchi | Korea | LAB | Cabbage, vegetables, sometimes seafood, nuts |
| Nan | India | *Saccharomyces cerevisiae*, LAB | White wheat flour |
| Ogi | Nigeria, West Africa | Lactic bacteria *Cephalosporium, Fusarium, Aspergillus, Penicillium* spp., *Saccharomyces cerevisiae, Candida mycoderma, C. valida,* or *C. vini* | Maize |
| Olives | Mediterranean | *Lc. Mesenteroides, Lb. plantarum* | Green olives |
| Pickles | International | *Pediococcus cerevisiae, Lb. plantarum* | Cucumber |
| Plara | Thailand | *Bacillus* sp., *Bacillus cerus, B. circulans, B. licheniformis, B. megaterium, B. pumilus* and *B. subtitils* | Fresh water and marine fish |

## 2.6 Physical-chemical, nutrition, microbiological and sensory characteristics of plant-based fermented probiotic beverages

### 2.6.1 Acidity

The acidity of the medium during fermentation is a key indicator of the metabolic activity of microorganisms under certain environmental conditions and is an important fermentation parameter (Hwang et al., 2004; Lee, Miyahara, & Noike, 2002). The acidity has a promote function on the growth of bacteria and the accumulation of products, therefore, it is necessary to monitor the pH during fermentation. Although most microorganisms can grow in the pH range of 3-4 the pH must be kept constant over a narrow range to achieve high growth rates and optimal product formation (Calsamiglia, Ferret, & Devant, 2002). The accumulation of organic acids increases the titratable acidity decreases the pH of the products (Freire, Ramos, & Schwan, 2015, Akin & Ozcan, 2017 and Menezes et al., 2018).

### 2.6.2 Viable cell counts

There are different types of probiotic bacteria used in plant-based fermented beverages, and their growth rates vary with the fermentation substrate and environment. Generally, probiotic bacteria grow rapidly under optimum fermentation conditions resulting in high viable cell counts after fermentation. Cell counts may change during storage of the fermented products depending on several factors including the presence of residual sugars, organic acids produced, buffering capacity of the medium, product composition, fermenting microorganisms, storage conductions and packaging.

Ertanto et al. (2009) reported cell counts in coconut yogurt ranging from 7 to 9 Log CFU /mL During fermentation of soymilk to reduce the beany flavour, Telang et al. (2010) reported cell counts of $10^9$ CFU /mL after 12 h of fermentation. Also, acceptable fermented soymilk supplemented with skimmed milk powder at 5% level with similar levels of viable cell counts have been reported (Telang et al., 2010). Commercial probiotic, *Lactobacillus paracasei* LBC-81, was used singly and in co-culture with potential probiotic yeasts, *Saccharomyces cerevisiae* CCMA 0731, *S. cerevisiae* CCMA 0732, and *Pichia* (*P.*) *kluyveri* CCMA 0615, to ferment a maize-based substrate (Menezes et al., 2018). All the tested strains presented viability higher than 6 log CFU /mL, as recommended for food probiotic products with the exception of the yeast *P. kluyveri* which decreased during fermentation and storage.

Similar results were reported during the fermentation of LAB and yeasts in cassava (Freire, Ramos, & Schwan (2015). There was a significant ($p<0.05$) growth of LAB (8 log CFU /mL) during the first 6 h. However, after 12 h, there was a significant ($p<0.05$) reduction of LAB when co-cultivated with the yeasts *S. cerevisiae* CCMA 0232 (7.6 log CFU /mL), *T. delbrueckii* CCMA 0234 (7.8 log CFU /mL), and *P. caribbica* CCMA 0198 (7.7 log CFU /mL). After 24 h of fermentation, the LAB population had increased to around 8 log CFU /mL.

### 2.6.3 Colour

The colour of fermented protein beverages changes depending on the substance of fermentation. Akin & Ozcan (2017) studied changes in the colour of fermented milk containing plant proteins during storage. The plant proteins included rice protein, wheat gluten, soy protein isolate and pea protein isolate. There were no marked differences in the L*value (lightness) of various beverages. They reported that the fermented milk beverage containing soy protein isolate recorded the highest L*value change while the fermented beverage of rice protein had the highest b* value (yellowness) due to the yellow rice protein. When *Streptococcus thermophilus* and *Lactobacillus bulgaricus* were used to ferment soy flour cowpea and peanut seed extract powders, the initial colour was similar with that of commercial buttermilk products (Schaffner & Beuchat, 1986). The b* value of soybean powder was the highest, while the cowpea and peanut powders displayed a similar degree of yellowness compared to the cowpea milk powder. In summary, little difference was distinguished between the colour changes of soybean, cowpea and peanut induced by *L. bulgaricus* and *S. thermophiles* (Schaffner & Beuchat, 1986).

### 2.6.4 Sugar

The sugar concentration may change during both the fermentation of plant-based beverages and their storage (Corona et al., 2016). Czarnecka et al. (1998) researched the effect of fermentable sugar levels on the dynamics of lactic fermentation during the fermentation of milled legume seeds and plant materials with *Lactobacillus plantarum*. They found that after the fermentation and extrusion, the levels of verbascose, stachyose and raffinose were significantly reduced by 80-90%. Czarnecka et al. (1998) have a similar found that lactose is readily metabolised to galactose and glucose by some *Kluyveromyces* and *Streptococcus* strains (Czarnecka et al., 1998). Magalhães et al. (2011) studied the chemical composition and

microbial ecology of the yogurt drink and found that the lactose concentration decreased within the 24 hours of fermentation, ranging from 45 to 35 mg /mL. Irigoyen (2005) reached a similar conclusion, with kefir fermented by kefir grains.

### 2.6.5 Nutritional characteristics

The nutritional composition of plant fermented foods has been widely reported (Canibe, Virtanen, & Jensen, 2007; Mbugua, 1987; Shekib, 1994; Akin & Ozcan, 2017; Magalhães et al., 2011). In general, the original nutrients present in foods and beverages are preserved during fermentation, and in many instances, the nutritional value of the food is increased (Canibe, Virtanen, & Jensen, 2007). For example, the partial hydrolysis of some proteins, which occurs during fermentation makes the food easier to digest and be absorbed when consumed. LAB can also produce vitamins such as vitamin C and B, which are necessary for the human body. Also, after fermentation, minerals such as calcium in the food do not change, but the lactic acid produced after fermentation effectively increases the utilization rate of calcium and phosphorus in the human body (Mbugua, 1987).

There is limited information on pea protein fermentation and its functional properties due to the low solubility of pea protein relative to the low pH environment (pH 4-5). Shekib (1994), investigated changes in the nutritional properties (non-protein nitrogen, crude and true protein, amino acids) of lentils and chickpeas during natural fermentation. This research showed that non-protein nitrogen increased significantly ($p<0.01$) in the fermented products, whereas the crude protein and true protein unchanged. Czarnecka et al. (1998) analysed viable cell counts in milled legume seeds fermented with *Lactobacillus plantarum* strains. Lactic fermentation and extrusion of bean and pea seeds increased ($p<0.05$) the “in vitro” protein and starch digestibility.

Akin & Ozcan (2017) investigated the storage-related changes in the physicochemical and sensory properties of non-fat fermented milk drinks that contained soy protein isolate, pea protein isolate, wheat gluten and rice protein. During storage, the protein content increased in fermented milk beverage. They also found rice protein and milk fermented beverage had the lowest total protein content, while fermented milk beverages with pea protein isolate had the highest protein concentration. Also, Magalhães et al. (2011) studied the microbial ecology and chemical composition of kefir beverage fermented for 24 hours. In their study, the protein

content increased from 2.12% to 3.19%, while fat decreased from 3.63% to 2.34%, and the calcium increased slightly from 0.21 mg /mL to 0.22 mg /mL.

### 2.6.6 Sensory characteristics

The consumer acceptability of foods is most directly expressed by their sensory profile. Thus, foods can be characterised by several factors which include colour, flavour, texture, smell, odour and taste (Dominy, 2004). Food sensory analysis is a test method that obtains objective results by sensory evaluation of various properties of foods based on human perception, followed by statistical analysis of the data (Favaro Trindade et al., 2001). Feng et al. (2013) investigated variations in sensory characteristics through the evaluation of the aroma of fermented soy sauce koji. The sensory analysis showed an obvious increase in “musty” and “soy sauce-like” odours, whereas the beany attribute diminished significantly throughout koji fermentation. Besides, Menezes et al. (2018) studied the sensory properties of a fermented maize-based substrate with the commercial probiotic *Lactobacillus paracasei* LBC-81 using the 1-9 points hedonic scale. The overall mean sensory scores for acceptance of the fermented koji increased from 5.07 to 5.45 ($p<0.05$). In a similar study, Puerari, Magalhães and Schwan (2012) reported a higher mean acceptance sensory score (7.8) of the fermented cocoa kefir beverage than the research of Menezes et al. (2018).

# 3. MATERIALS AND METHODS

## 3.1 Introduction

The main aim of this research was two-fold, to reduce the yellowness of pea protein powder and then reduce the beany-flavour by chemical purification, and then add the purified paste into coconut milk for lactic acid fermentation. The study was conducted in three integrated phases. All the experiments were conducted in triplicate and all analyses were either duplicated or triplicated.

The first phase used the isoelectric precipitation and salt extraction methods to purify the commercial pea protein powder (Schindler et al., 2012). The purpose of this step was to reduce the yellowness of the pea protein powder to a creamy colour protein paste more suitable for wider applications including the production of the fermented beverage. The colour and protein content of the purified samples (pea protein paste) were compared with the original commercial pea protein powder. The second phase investigated the best fermentation conditions of fermented pea protein-coconut milk beverage (optimization). The fermentation mixture of refined pea protein paste and organic coconut milk (Ceres Organics, NZ) was fermented by a mixed lactic acid bacteria culture. The fermentation was conducted in two parts. The first part comprised a single-factor test which investigated the effect of three factors (temperature, time and pea protein paste concentration). The second part used the orthogonal test to investigate the optimum fermentation conditions for the fermented pea protein-coconut milk beverage. During fermentation, pH, titratable acidity (TA), viable cell counts (VCCs), colour and protein content were determined. In the orthogonal test, supplementary information was obtained through sensory evaluation of the fermented beverage using a semi-trained sensory panel (n=18). The orthogonal test is intended to screen optimum conditions using a reduced number of experiments (Oztop, Sahin, & Sumnu, 2007).

The main purpose of phase two was to reduce the beany flavour of the pea protein through fermentation to develop a new fermented pea protein-coconut milk beverage. In phase three, the stability of the fermented pea protein coconut beverage, which included the sensory characteristics were determined during storage (4 °C) for 21 days. An overview of the three phases used in this study is shown in Figure 3.1

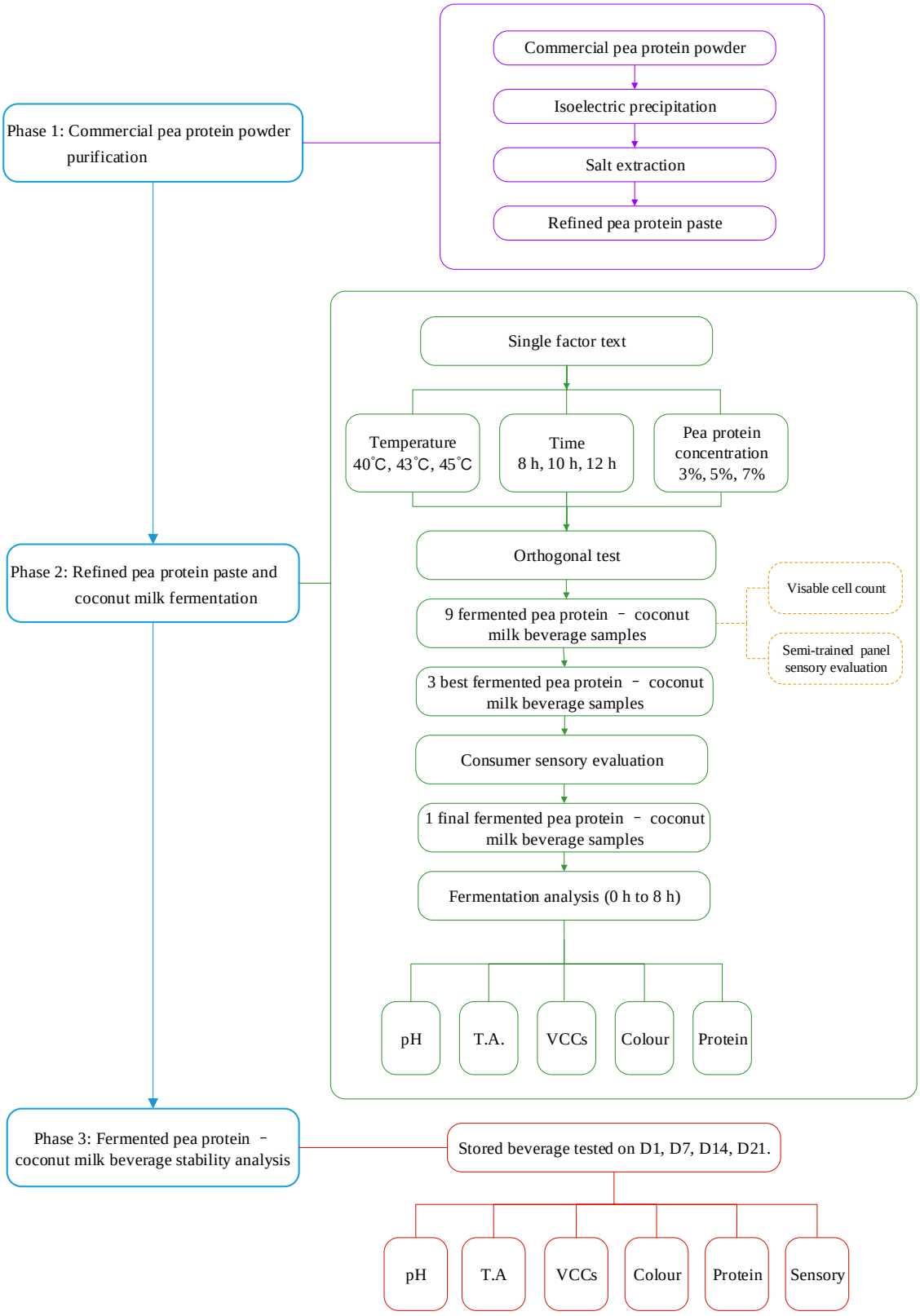



Figure 3.1 Experimental phases of the study

Notes: VCCs = Viable cell counts, T.A. = titratable acidity

## 3.2 Description of materials

A dark yellow commercial pea protein powder (Roquette S85F, France) was supplied by White Rock Foods Limited (Auckland, New Zealand). The starter culture VEGE 053 LYO (Danisco, USA) which is recommended for vegetable and plant fermentations was supplied by Dupont® Limited (Auckland, New Zealand). The culture contained *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Lactobacillus delbrueckii* subsp. *lactis*, *Bifidobacterium lactis* (HN019™) and *Lactobacillus acidophilus* (NCFM®). A dosage of 10-20 DCU /100 L was used as per supplier recommendations. Organic coconut milk (Ceres Organics, NZ) was purchased from a local supermarket in Auckland, New Zealand.

## 3.3 Phase 1: Refining of commercial pea protein powder

### 3.3.1 Description of the refining method

The isoelectric precipitation and salt extraction methods were used to purify the commercial protein powder with minor modifications (Schindler et al., 2012). The protein powder (100 g) was suspended in about 90 mL distilled water and then made up to 1 L to give a 10% solution. The mixture was heated in a water bath (Grant, Global Science, NZ) with gentle mixing using a vortex mixer (Dalson, Dalsonware Pty. Ltd., Australia) until the temperature had stabilised at 60 °C which is ideal for the protein extraction (Kizer, Renninger, & Stiles, 2019). The pH was adjusted to 9 using 1 M NaOH (Univar, Ajax Finechem Pty Ltd, NZ) and the solution was mixed using a vortex mixer (Dalson, Dalsonware Pty. Ltd., Australia) for 10 minutes. The extract was separated by centrifuging (Sorvall™ Legend™ X1, Fisher Scientific, NZ) at 16211 g for 10 minutes. The supernatant was removed and further centrifuged to remove any remaining precipitation. Ten (10) g calcium chloride (4 M, $CaCl_2$) (Sigma-Aldrich Corporation, USA) were added to the supernatant. The mixture was adjusted to pH 5 with 1 M hydrochloric acid (HCl) (Sigma-Aldrich Corporation, USA), followed by centrifugation for 10 minutes at 16211 g. The pea protein has the lowest solubility at pH 5 (Taherian et al., 2011); The isoelectric point of pea protein lies between pH 4 and pH 6. The supernatant was discarded and the pea protein paste (pellet) was collected. The paste was re-suspended in water (30 x dilution by weight) and then mixed for 1 minute using a homogenizer (Thomas Scientific LLC, USA). The sample was further centrifuged (16211 g) for 5 minutes and the protein paste was collected. An overview of the refining process is shown in Figure 3.2.

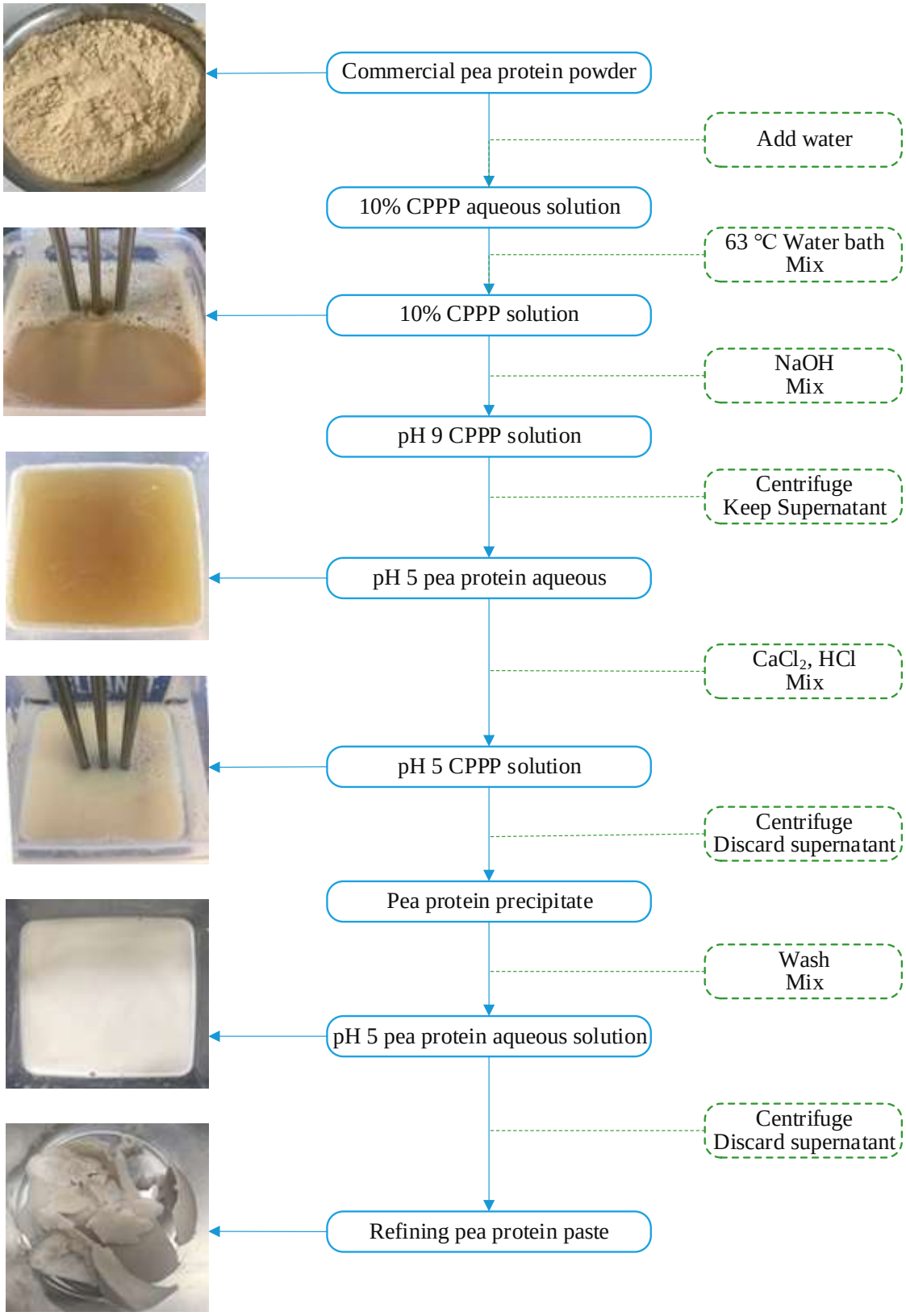



Figure 3.2 Modified commercial pea protein powder refining procedure (Schindler ey al., 2012)

Notes: CPPP = commercial pea protein powder; Photos captured by iPhone XR, Apple Inc., California, USA.

### 3.3.2 Measurement of colour

The colour of the commercial pea protein powder and refined protein isolate obtained from the commercial pea protein powder were measured using the Konica Minolta spectrophotometer (CM-5, Japan) following the method of Kurtmann et al. (2009). According to the L*, a*, b* colour system, L* represents lightness (0 is black and 100 is diffuse white), a* is the green /red scale (negative values represent green, positive values are red) and b* is the blue /yellow scale (negative values indicate blue, positive values are yellow) (Alqahtani, Aljurais, & Alshaafi, 2012). Before the measurement, the spectrophotometer was allowed to warm up for one minute. Commercial pea protein powder and refined protein isolate (0.3 g) were mixed in three (3) mL water then transferred into four (4) mL plastic cuvettes (Sigma Aldrich, NZ) respectively and the colour of the samples were measured using the spectrophotometer.

## 3.4 Phase 2: Selection optimum fermentation conditions of fermented pea protein-coconut milk beverage

### 3.4.1 Single factor test design

The effects of different fermentation temperatures, protein concentrations and fermentation times on the mixture of refined pea protein paste and organic coconut milk (Ceres Organics, NZ) were investigated using the single factor test.

#### 3.4.1.1 Effect of fermentation temperature on the fermentation of pea protein-coconut milk beverage

According to previous studies (Leroy & De Vuyst, 2004; Yildiz 2009), the optimum fermentation temperatures for *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, *L. delbrueckii* subsp. *lactis*, *B. lactis* and *L. acidophilus* in (fermented) beverages range between 35 °C and 45 °C with pH ranging from 3.5 and 4.5. In these studies, the fermenting bacteria were inoculated either singly or mixed. In our study, the selected fermentation temperatures (fixed factors) were 35 °C, 37 °C, 40 °C, 43 °C and 45 °C with final pH between 3.5 and 4.5.

Table 3.1 Effect of temperature on the fermentation of 100 mL coconut milk for 12 h

| Experiment | Fermentation temperature (°C) |
|---|---|
| 1 | 35 |
| 2 | 37 |
| 3 | 40 |
| 4 | 43 |
| 5 | 45 |

For the experiments shown in Table 3.1, 5×100 mL organic coconut milk (Ceres Organics, NZ) samples were pasteurized at 95 °C in a water bath (Grant, Global Science, NZ) for 15 minutes and then cooled to 30 °C. The temperature was monitored using a thermocouple (Fluke 51, Fisher Scientific, NZ). When the temperature of the coconut milk had stabilised at 30±1 °C, the starter culture (VEGE 053 LYO) was directly inoculated into the coconut milk at a dosage of 20 DCU /100 L (0.014 g /L). The mixture was agitated for about 10 minutes using a vortex mixer (Dalson, Dalsonware Pty. Ltd., Australia) at low speed to avoid foaming and incorporation of air. The inoculated coconut milk was allowed to ferment for 12 h in the respective water baths set at 35 ℃, 37 ℃, 40 ℃, 43 ℃ and 45 ℃. pH was measured directly every 2 h by a digital pH meter (Sartorius PB-20, USA) equipped with a glass electrode (AOAC 981.12, 2005). The pH meter was calibrated with standard buffer solutions (LabServ, Thermofisher, NZ) at pH 4.0 and 7.0 before measurement.

#### 3.4.1.2 Effect of refined pea protein concentration on the fermentation of pea protein-coconut milk beverage

The protein concentration of fermented beverages in the market ranges from 3 to 12% (Corbo et al., 2014; Özer & Kirmaci, 2010). The fermented products include ginger beer, milk /water kefir and kombucha. To study the effect of pea protein concentration on the fermentation of fermented pea protein-coconut milk beverage, five refined pea protein paste concentrations were used (Table 3.2) with 45 °C (result from section 3.4.1.1) as the fermentation temperature.

Table 3.2 Concentrations of refined pea protein paste (%) added to 100 mL coconut milk for fermentation at 45 °C for 12 h

| Experiment | Refined pea protein (%) |
|---|---|
| 1 | 3 |
| 2 | 5 |
| 3 | 7 |
| 4 | 9 |
| 5 | 11 |

5 × 100 mL organic coconut milk samples were pasteurised and cooled as previously described (section 3.4.1.1). When the temperature of the coconut milk had stabilised to 30±°C, variable amounts of refined pea protein paste (Table 3.2) were added to the respective milk samples and then mixed (Dalson, Dalsonware Pty. Ltd., Australia). The starter culture (VEGE 053 LYO) was directly inoculated into the five treatments of refined pea protein paste- coconut milk mixtures at the same dosage used in section 3.4.1.1, and then mixed as previously described. The mixtures were fermented at 45 ℃ in a water bath for 12 h, with 2-hourly measurements of pH as previously described (section 3.4.1.1).

### 3.4.1.3 Effect of time on the fermentation of pea protein-coconut milk beverage

The starter culture VEGE 053 LYO contains several LABs which are representative members of commercial probiotics. Although the species of bacteria in the culture are not designated as probiotics, their presence in the final fermented product may be beneficial (Marsh et al., 2014). FAO /WHO states that to exert a beneficial effect to human health, the probiotics must be alive and available in high numbers, at least $10^6$ colonies forming per unit (CFU) at the time of consumption (2002). To select the optimum fermentation time for the fermented pea protein-coconut milk beverage, the experiment was set up as described in section 3.4.1.1, but the fermentation was allowed to continue for 24 h at 45 ℃, 3% pea protein concentration (results from section 3.4.1.1 and 3.4.1.2). The samples were collected every 2 h and stored At -18 °C (Fisher & Paykel, NZ) for the enumeration of viable cell counts (VCCs).

### 3.4.1.4 Enumeration of viable cell counts (VCCs)

Total viable cell counts of the beverage during fermentation were determined by pour plating diluted samples on De Man, Rogosa and Sharpe (MRS) agar and M17 agar (Oxoid, UK). One (1) mL of each sample was mixed with 9 mL sterile peptone water (Merck, Germany), and then

serial dilutions ($10^1$ to $10^8$) were prepared and plated using the pour plate method (Jackson et al., 2000). The MRS agar plates were used to enumerate *L. delbrueckii* subsp. *bulgaricus*, *L. delbrueckii* subsp. *lactis*, *B. lactis* (HN019™) and *L. acidophilus* (NCFM®), whereas M17 agar (Oxoid, UK) was used to enumerate *S. thermophilus*. The solidified MRS agar plates were incubated at 37 °C for 72 h under anaerobic conditions using an Anaergen park (AN0035A) (Mitsubishi Gas Chemical Company Inc., Japan) and 48 h for M17 agar plates at 37 °C under aerobic conditions. Results of the enumerated cell counts were expressed as log colony forming units per milliliter (CFU /mL).

### 3.4.2 Orthogonal test

#### 3.4.2.1 Description of the orthogonal test design

Orthogonal arrays and analysis of variance (ANOVA) have been used to determine the effects of treatment factors on characteristic properties of the samples (Jeyapaul, Shahabudeen, & Krishnaiah, 2005; Oztop, Sahin, & Sumnu, 2007; Unal & Dean, 1990). Orthogonal tests use reduced number of experiments to optimise processing conditions, thereby reducing the cost and time of experimental trials.

Preliminary results from the single factor test (section 3.4.1) were used to design the experiments in this phase. Based on the single factor test results (section 3.4.1), three fermentation temperatures (40 ℃, 43 ℃, 45 ℃), three protein concentrations (3%, 5%, 7%, w /v) and fermentation times (8, 10, 12 h) were selected as shown in Table 3.3.

Table 3.3 Three levels of fermentation conditions with three factors for the orthogonal experiments to optimise the fermentation of refined pea protein paste-coconut milk beverage

| Level | Factor A (fermentation temperature, °C) | Factor B (fermentation time, h) | Factor C (protein concentration, %) |
|---|---|---|---|
| 1 | 40 | 8 | 3 |
| 2 | 43 | 10 | 5 |
| 3 | 45 | 12 | 7 |

The standardised orthogonal experimental design uses an L9 ($3^3$) array with three columns and nine rows (Zhang, Chen, & Kirby, 2007). The L9 ($3^3$) array has eight degrees of freedom with the capacity to use up to three control factors, each at three levels. Thus, nine experimental treatments (formulations) were conducted using a combination of levels for each control factor (fermentation temperature, fermentation time and pea protein concentration) as shown in Table

3.4. Levels of the three factors were selected based on the previous single factor experimental results (section 3.4.1). Nine formulations (experiments 1-9) and corresponding samples were developed in this phase. To determine the effects of protein concentration on the fermented beverages, the samples were analysed for VCCs and a semi-trained sensory panel evaluated the beverages at the end of the fermentation period.

Table 3.4 Orthogonal tests for refined pea protein paste-coconut milk fermentation

| Experiment | Factor A (fermentation temperature, °C) | Factor B (fermentation time, h) | Factor C (protein concentration, %) |
|---|---|---|---|
| 1 | 40 | 8 | 3 |
| 2 | 40 | 10 | 5 |
| 3 | 40 | 12 | 7 |
| 4 | 43 | 8 | 5 |
| 5 | 43 | 10 | 7 |
| 6 | 43 | 12 | 3 |
| 7 | 45 | 8 | 7 |
| 8 | 45 | 10 | 3 |
| 9 | 45 | 12 | 5 |

Note: Orthogonal design was generated by SPSS Version 22 (IBM™, New York, USA) software.

For experiments 1-3 (Table 3.4), 3%, 5% and 7% refined pea protein paste (w /v) in 100 mL coconut milk samples, were fermented (40 °C) in a water bath for 8, 10 and 12 h, respectively. For experiments 4-6, samples containing 5%, 7% and 3% refined pea protein in the coconut milk were fermented at 43 °C for 8, 10 and 12 h. The setup for experiments 7 and 9 was similar to experiments 1-6, samples containing 7%, 3% and 5% refined pea protein in the coconut milk were fermented at 45 °C for 8, 10 and 12 h.

3.4.2.2 Semi-trained sensory panel sensory evaluation

The aim of the semi-trained sensory panel sensory evaluation was to determine the most accepted of the three beverage samples. The semi-trained sensory panel consisted of six participants who consumed or were familiar with plant fermented beverages. Before evaluation, panelists were asked to read the information sheet and signed the participant consent form (Appendix D) which had been approved by Massey University Human Ethics Committee (4000020456). The semi-trained sensory panel evaluated nine fermented pea protein-coconut milk beverages (Table 3.4) for appearance, aroma, sourness, sweetness, mouthfeel, after-taste

and the beany flavour. Additional information was collected using the 9-point hedonic rating scale for the overall acceptability, in the sensory laboratory at Massey University, Auckland Campus. For the sensory evaluation, 20 mL chilled (4 °C) samples were served to the participants in 25 mL plastic cups. Participants were required to rinse their palate with still mineral water between each sample.

### 3.4.3 Consumer sensory evaluation

The samples selected by the semi-trained sensory panel were subjected to further sensory evaluation by consumer sensory panelists (n=90) using the 9-point hedonic rating scale on three different occasions. The main purpose of the consumer sensory evaluation was to select the most acceptable fermented pea protein coconut beverage by a large number of consumer sensory participants. The consumer panelists evaluated the three fermented beverages selected by the semi-trained sensory panel (section 3.4.2.2). The samples were evaluated for appearance, aroma, sourness, sweetness, flavour, mouthfeel, after-taste and overall acceptability of each sample. Before sensory evaluation, the samples were coded by 3-digit random numbers generated by R Studio software (R-Studio, USA). In this section, consumer sensory panelists were presented with the same ethics documents as described in section 3.4.2.2.

### 3.4.4 Analysis of the physicochemical characteristics of pea protein-coconut milk beverage during fermentation

Various parameters (pH, T.A., VCCs, colour, sugar, organic acid, crude protein) were determined during the fermentation of the final pea protein-coconut milk beverage (sample 1：the result from section 3.4.1, 3.4.2 and 3.4.3). The methods for measurement of pH and enumeration of VCCs were described in section 3.4.1.1 and 3.4.1.4, respectively. The methods used for the analysis of T.A., sugar, organic acid, crude protein and measurement of colour are described in the subsequent sections.

#### 3.4.4.1 Determination of titratable acidity

Titratable acidity was determined by acid-base titration using 0.1% phenolphthalein (Univar, Ajax Finechem Pty Ltd, NZ) as an indicator (AOAC 947.05, 2005). Standardized 0.1 M sodium hydroxide (NaOH) (Univar, Ajax Finechem Pty Ltd, NZ) was used to titrate against 5 g of

fermented pea protein-coconut milk beverage which had been pre-weighed on an analytical balance (Appliance Check, NZ) and mixed with 20 mL of distilled water. About 2 mL (3-4 drops) of phenolphthalein solution (1%) (Univar, Ajax Finechem Pty Ltd, NZ) was added to the mixture and swirled. The test mixture was titrated against NaOH until the first persistent (30 s) pink colour and the end-point of pH 8.2 was achieved. Calculated titratable acidity was expressed in grams of lactic acid per liter of sample. The analysis of titratable acidity was conducted in duplicate and the experiment was repeated twice.

$$\%\ \text{Lactic acid} = \frac{\text{volume of NaOH used(ml)} \times 0.0090}{\text{sample weight (g)}} \times 100$$

1 mL 0.1 M NaOH = 0.009 g Lactic acid;
1 mL of sample ≈ 1 g of sample

3.4.4.2 Analysis of sugar

Sugar affects the rate of fermentation reactions. Three percent sugar could speed up fermentation (Corona et al., 2016; Magalhaes et al., 2010). Therefore, analysis sugar content is important to study fermentation process. Determination of sucrose, glucose and fructose in fermented pea protein-coconut milk beverage was performed by high-performance liquid chromatography (HPLC) system following the method of Stadie (2013) with some modifications. The HPLC system consisted a model LC-10AT HPLC (Shimadzu Corp, Japan), column oven (CTO-10AS, Shimadzu Corp, Japan), autoinjector (SIL-10A, Shimadzu Corp, Japan) and a system controller (SCL-10A, Shimadzu Corp, Japan) equipped with an Ultra Violet (UV) detector (SPD-10A, Shimadzu Corp, Japan) and a Refractive Index (RI) detector (RID-10A, Shimadzu Corp, Japan). Distilled water which was previously filtered through anylon membrane filter 0.22 um (Ø = 47 mm) (Merck, Germany) and degassed with ultrasonic bath (Bandelin Sonorex Super RK510, Germany) was used as the mobile phase at 0.5 mL /min, a separation Rezex RCM- Monosaccharide, RCM $Ca^{2+}$ (8% cross-linked resin) column (300 × 7.8 mm) was used for the determination at 40 °C. Before analysis, a series of standard sugars: sucrose (≥99.5%, Sigma Aldrich, NZ) standards, glucose (≥99.5%, Sigma Aldrich, NZ) standards and fructose (≥99%, Sigma Aldrich, NZ) were prepared as external standards. The concentration of sucrose and fructose standards in distilled water were 0.5%, 1%, 1.5%, 2%, 2.5%, 3% (w /v in water) and the concentration of glucose standards were 0.2%, 0.4%, 0.6%, 0.8%, 1%, 1.2% (w /v). All standards and test samples were previously filtered through 0.22-

µm syringe filters (Merck, Germany) and stored in 2 mL vials (Shimadzu Corp, Japan). Automatic uploading (1 µl) of samples was conducted in duplicate and each sugar was identified and quantified by comparing with retention times and peak areas of the standards using Shimadzu LC solutions software (Shimadzu Prominence, Japan). The concentration of sugars in the beverage was interpolated from the standard calibration curves.

#### 3.4.4.3 Analysis of organic acids

Lactic acid and acetic acid in the fermented pea protein-coconut milk beverage were analysed by HPLC using UV detection, according to Stadie (2013) with minor modifications. The HPLC model LC-10AT (Shimadzu Corp, Japan) equipped with an autoinjector (SIL-10A, Shimadzu Corp, Japan), column oven (CTO-10AS, Shimadzu Corp, Japan), system controller (SCL-10A, Shimadzu Corp, Japan) and a dual detection system consisting of a Refractive Index (RI) detector (RID-10A, Shimadzu Corp, Japan) and an Ultra Violet (UV) detector (SPD-10A, Shimadzu Corp, Japan) was used for the analyses. A separation Rezex ROA-Organic Acid (8% cross-linked resin) column (300×7.8 mm) was used for the analyses at 40 ℃, sulphuric acid (Fisher Scientific, UK) (0.005 N) was used as the mobile phase at a flow rate of 0.5 mL /min. Prior to analysis, standard solutions and test samples were filtered through 0.20 µm syringe filters (Terumo, Australia) and kept stored in 2 mL vials (Shimadzu Corp, Japan) for chromatographic analysis. Automatic injections (10 µl) were performed in duplicate. Individual organic acids were identified and quantified by comparison of their retention times and peak areas respective to their standards (lactic acid, 252476 ≥95%, Sigma Aldrich, NZ; acetic acid, 2789, ≥99.5%, Fisher scientific, UK). The concentrations of lactic acid and acetic acid standard used were 0.3125%, 0.625%, 1.25%, 2.5%, 5% (w /v). Peak areas were integrated using Shimadzu LC Solutions Software (Shimadzu Prominence, Japan). The quantification of organic acids was performed using calibration curves obtained from the standard compounds.

#### 3.4.4.4 Analysis of crude protein

The quantity of protein in the pea protein coconut fermented beverage was analysed using the Kjeldahl method (Lynch & Barbano, 1999). The first step was the digestion of the sample. Samples of the fermented pea protein-coconut milk beverage were separately weighed (0.5-1 g) and transferred into respective digestion tubes with two Kjeltabs tablets (Univar, Ajax Finechem Pty Ltd, NZ). A blank digestion (control) was also included in the analysis of crude protein. The samples were digested at low temperature, gradually increasing the intensity of

heat to 420 ℃ using the Kjeltec™ 8400 digestion unit (FOSS, Denmark). Digestion was stopped when the samples were clear which took about 4 h. After digestion, the samples were removed carefully from the heating unit and allowed to cool distilled water (70 mL) was then added to each tube and mixed.

The next step was the distillation of the samples using Kjeltec 8400 (FOSS, Denmark) which was done according to the instructions of the manufacturer. When the distillation was completed, the distilled samples were titrated against 0.1 M HCl to a grey-mauve end-point (reference).

Calculation used to determine % nitrogen and protein content in samples:

$$\% \text{ Nitrogen} = \frac{(A \times B) \times 14 \times 100}{1000 \times C}$$

Where A = mL HCl used;
B = exact molarity HCl;
C = weight (g) of test sample used;

Protein (%) = % Nitrogen x conversion factor

Note: the conversion factor is 6.25.

### 3.5 Phase 3: Stability of the fermented pea protein-coconut milk beverage

Four 500 mL pea protein paste coconut milk mixtures containing 3% refined pea protein were prepared and fermented at 40 ℃ /8 h using the lactic starter culture 20 DCU VEGE 053 LYO as previously described in section 3.4.1.1. After fermentation, the four bottles of fermented pea protein-coconut milk beverage products were stored at 4 ℃ (Fisher & Paykel, NZ) for 21 days. One sample (500 mL) was retrieved from chilled storage for determination of various parameters (pH, colour, titratable acidity, VCCs, sugar, organic acid, crude protein) after storage for 1, 7, 14 and 21 days. The other samples were also evaluated by a semi-trained sensory panel (n=15) at day 1, 7, 14 and 21 as described in section 3.4.2.2.

### 3.6 Statistical analysis of data

The data were analysed by the SPSS Version 22 (IBM™, New York, USA) software using the univariate of General Linear Model (GLM) analysis of variance (ANOVA). Data were expressed as mean ± standard deviation (SD) or ± standard error of the mean (SEM) and were tested for normality and homogeneity using the Kolmogorov-Smirnov and Levene Test at 95% confidence level. Non-normally distributed data were log transformed to obtain normality. Normally distributed data were further analysed by one-way analysis of variance (ANOVA). ANOVA was used to investigate the effects of the concentration of pea protein, fermentation temperature and fermentation time on the physicochemical, microbiological and sensory properties of the product at $\alpha$=0.05. The least significant difference (LSD) multiple comparisons test was applied to separate significant differences between group means at 95% confidence interval.

# 4. RESULTS AND DISCUSSION

## 4.1 Phase 1: Refined commercial pea protein powder

### 4.1.1 Colour of refined commercial pea protein powder

The appearance of food is generally the first impression the consumer encounters. In addition, the appearance of food can be an indicator of freshness, preservation state and flavour expectation (Hutchings & Hutchings, 1999; Chung et al., 2016). The purification step aimed to transform the yellow coloured commercial pea powder to a white coloured refined pea protein paste. Then to broaden its applications in food, including fermented dairy-like beverages. For dairy-like beverages, whiteness is one of the most important factors for consumer acceptance (Kwok et al., 1999). It was therefore important to measure the colour of the purified pea protein and compare its colour to the commercial pea powder (Figure 4.1). Figure 4.1 shows that the colour of the commercial pea powder was transformed into a white refined pea paste.

a  b 

Figure 4.1 Images of commercial pea protein powder (a) and refined pea protein paste (b)

Note: Images were captured by iPhone XR, Apple Inc., California, USA

Figure 4.2 compares the colour of the commercial pea protein powder with the purified pea protein paste. The lightness (L*) increased from 76.88±0.11 to 81.14±0.76, redness (a*) decreased from 3.08±0.02 to 0.35±0.06 and yellowness (b*) decreased from 16.32±0.09 to 6.86±0.12 ($p<0.05$) (Appendix E). The higher L* values of the refined pea protein paste (pH 5) reflected a lighter and white colour than the commercial pea protein powder. The positive a* and b* values of the purified paste indicated that the paste was a lighter yellowish-red colour than the commercial pea powder. The colour change may be attributed to the salt extraction, with the yellow pigment from the commercial pea protein powder being reduced or eluted during purification (Taylor, Fields, & Elder, 2004).

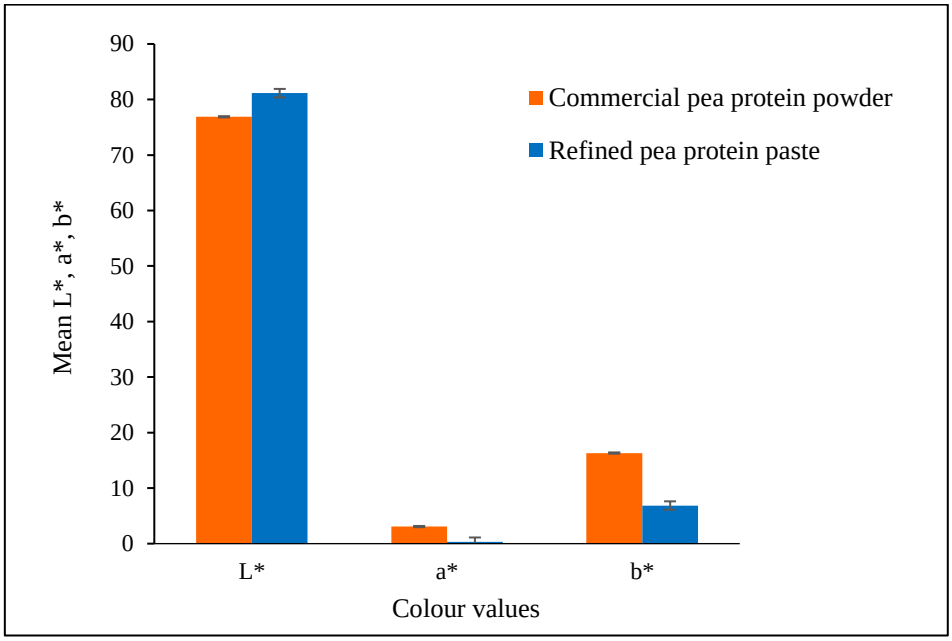



Figure 4.2 Mean colour values of commercial pea protein powder and refined pea protein paste

Notes: Error bars are means ± standard deviation; n=3. L* represents lightness (0 is black and 100 is diffuse white); a* is the greenness /redness (negative values represent green, positive values represent red) and b* is the blue /yellow (negative values indicate blue, positive values are yellow) (Alqahtani, Aljurais, & Alshaafi, 2012).

Sumner, Nielsen and Youngs (1981) reported a higher colour values of the pea paste (pH 4.5) than the present study. On the contrary, the refined pea protein (pH<4) in the study of Kizer, Renninger and Stiles (2019) had lower colour values compared to the present study. The differences in the colour values in these different studies were probably attributed to different acidic levels of the refined pea proteins. Because Khan and Farooqui (2011) stated that anthocyanins produce a red to yellow colour when the environment changes from alkaline to acidic. The yellowish-red colour was expected in the products due to the acidic property of purified pea protein (Stintzing & Carle, 2004).

### 4.1.2 Protein content of purified pea protein

Figure 4.3 shows the protein concentration of the commercial pea protein powder and the purified pea protein paste. The protein concentration of refined pea protein paste was 17.31±0.32%, which was lower than the protein concentration of the commercial pea powder (77.44±0.56%) ($p<0.05$). The differences in the protein levels of the two products were probably attributed to their different water content. Comparing with the dry commercial pea

powder which has low water content, the refined pea protein paste has a large amount of water in it. As predicted, the protein concentration of dry refined pea protein paste (92.63±1.20%) was higher than the commercial pea powder (77.44±0.56%) by around 15% after the extraction process due to the protein enrichment ($p<0.05$) (Appendix E).

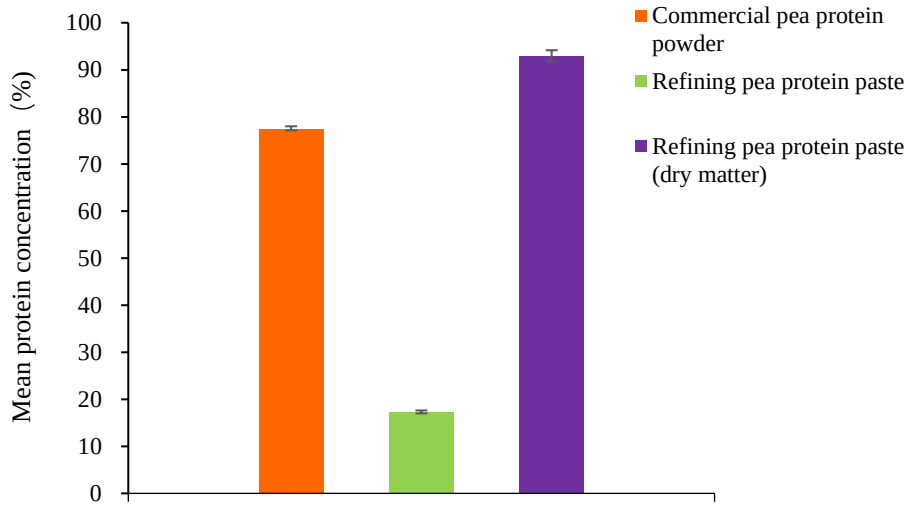



Figure 4.3 Mean pea protein concentrations of commercial pea protein powder, refined pea protein paste and dry refined pea protein paste

Notes: Error bars are means ± standard deviation; n=3.

The protein concentration of the refined pea protein paste was similar to the patent of Kizer, Renninger and Stiles (2019). In their patent, the mean pea protein concentration of the refined pea protein paste was 17% (w /w). The results were similar to those of our study because we used same raw material (Roquette S85F) and the same methods for refining and extraction.

However, Boye et al. (2010) reported lower protein concentrations (63.9-81.7%) of pea protein paste using isoelectric precipitation was, which were lower than our results (92.63±1.20%). The differences in the protein concentrations may be attributed to the different methods used in their studies. Boye et al. (2010) only used the isoelectric precipitation method to refine pea protein which was suitable for crude extraction of protein. Whereas, we used both isoelectric precipitation and salt extraction methods to refined the pea protein (Makri, Papalamprou, & Doxastakis, 2005). The salt extraction method combined with the isoelectric precipitation method could assist in producing higher concentration refined protein (Murray, Pizzorno, &

Pizzorno, 2005). The protein concentration obtained in this study (92.63±1.20%) was slightly higher than the study of Sumner, Nielsen and Youngs (1981). In their study, the protein content of pea protein isolate ranged from 83 to 90% for the pea protein isolates. The addition of salt extraction method and the higher protein concentration of the original sample in the present study may contribute to the differences in protein content of the study by us and by Sumner, Nielsen and Youngs (1981). The high protein concentration of dry refined pea protein paste suggested that the purification method was effective in purifying the commercial pea powder and improving the protein content.

### 4.1.3 Summary

The purification process produced a white (L*: 81.14±0.76) refined pea protein paste. The protein concentrations of wet refined pea paste and dry refined pea paste were 17.31±0.32% and 92.63±1.20%, respectively. The refined pea protein paste was added to coconut milk to develop a new dairy-like fermented beverage.

## 4.2 Phase 2: Development of a fermented pea protein-coconut milk beverage.

In Phase 2, the refined pea protein paste was added to organic coconut milk for fermentation with a starter culture VEGE 053 LYO. Single-factor tests and orthogonal experiments were conducted to select (optimise) the fermentation conditions of the fermented pea protein-coconut milk beverage. Semi-trained sensory panel sensory evaluation and consumer sensory evaluation were conducted to select a fermented pea protein-coconut milk beverage with the most acceptable sensory properties. Various parameters (pH, T.A., VCCs, colour, sugar, organic acids and protein content) were determined to characteristics the fermented milk.

### 4.2.1 Selection (Optimisation) of the fermentation conditions using the single factor test

Fermentation conditions comprising the starter culture used, type of raw materials, sugar concentration, fermentation temperature and time have important effects on the fermentation process (Wang et al., 2015). Therefore, to develop a full-bodied and stable fermented beverage, the fermentation conditions must be optimised. The starter VEGE 053 LYO 200 DCU culture used was specific for vegetal and plant fermentation (Dupont company, Auckland, New Zealand). Therefore, in this experiment on the development of fermented pea protein-coconut milk beverage, the fermentation temperature, fermentation time and pea protein concentration were the main factors studied for optimisation.

#### 4.2.1.1 Effect of temperature on fermentation

The effect of five temperatures (35 °C, 37 °C, 40 °C, 43 °C and 45 °C) on the fermentation of the pea protein-coconut milk were investigated. The pea protein-coconut milk fermentation process was monitored by measuring pH (Yoon, Woodams, & Hang, 2005). Figure 4.4 shows that fermentation at higher temperatures accelerated the fermentation process. After fermentation for 12 h, the pH decreased from 6.2±0.00 to 4.19±0.07, 4.13±0.05, 4.09±0.06, 3.98±0.08, 3.92±0.05 respectively, in samples fermented at 35 °C, 37 °C, 40 °C, 43 °C and 45 °C ($p<0.05$) (Appendix E). The pH decreased slowly during the first 2 h, then decreased rapidly between 2 h and 8 h. After fermentation for 8 h, the pH gradually decreased up to 12 h.

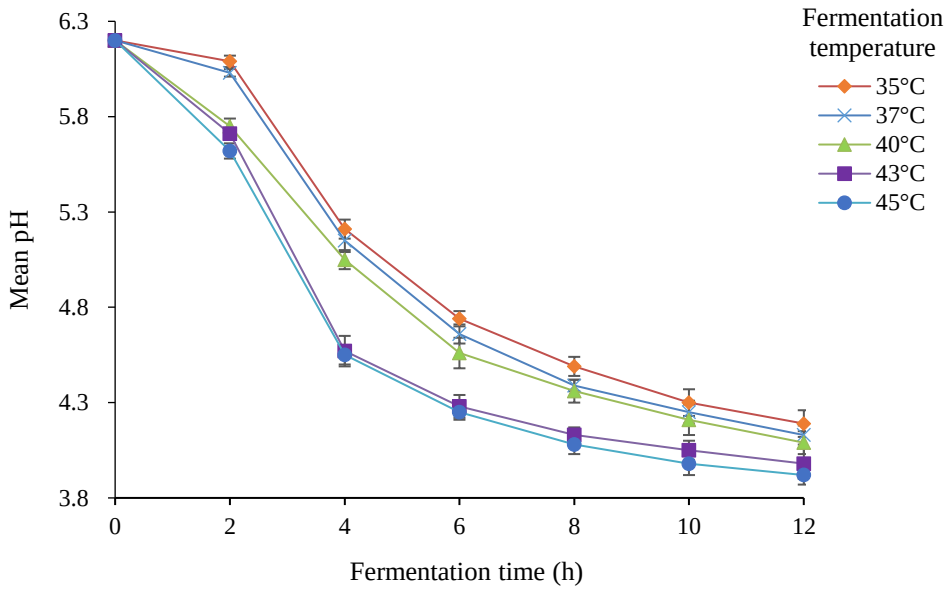



Figure 4.4 Mean pH of refined pea protein paste-coconut milk during fermentation at different temperatures for 12 h

Notes: Error bars are means ± standard deviation; n=3.

The decrease in pH during fermentation was caused by the production of organic acids, during the fermentation process, with glucose being converted to lactic acid, $CO_2$ and ethanol (Makarova et al., 2006; Moraes Filho et al., 2016; Østlie et al., 2003). The optimum growth temperature of LAB varies between species and strains of cultures. In soymilk fermented by *Lactobacillus plantarum* BG 112, the optimum temperature was 37 °C, while *Lactobacillus acidophilus* LA 3 showed better growth at 31 °C (Moraes Filho et al., 2016). In contrast, *L. reuteri* SD 2112 exhibited rapid growth in milk when incubated at 37 °C and 45 °C (Østlie et al., 2003). However, in the present study involving fermentation of coconut milk with the VEGE 053 LYO starter culture, rapid decreases in pH were observed at higher (40 °C, 43 °C and 45 °C) temperatures. From the results, it may be concluded that higher temperature was supported better growth of the VEGE 053 LYO in the coconut milk.

After fermentation 12 h, the most significant pH decrease (6.2±0.00 to 3.92±0.05) was recorded in the sample fermented at 45 °C. Therefore, 45 °C was selected for the fermentation of pea protein-coconut milk beverage in the next two experiments (section 4.2.1.2 and 4.2.1.3).

4.2.1.2 Effect of refined pea protein paste concentration on changes in pH of the fermentation mixtures

Five concentrations of refined pea protein paste (3%, 5%, 7%, 9% and 11%) were used to evaluate the effect of the pea protein concentration on the rate of pea protein-coconut milk fermentation at 45 °C. The rate of fermentation was determined by measuring changes in the pH of the fermentation mixtures.

The results showed that there were no significant differences of the pea protein paste concentrations (3%, 5%, 7%, 9% and 11%) on the changes in pH of the mixtures during fermentation ($p>0.05$) (Appendix E). After fermentation, the average pH of the beverages was 4.04±0.08, 4.09±0.06, 4.13±0.06, 4.19±0.05 and 4.26±0.07 for the respective treatments. The fastest change in pH was recorded in the mixture that contained the lowest pea protein paste concentration in the fermented pea protein-coconut milk beverages (Figure 4.5).

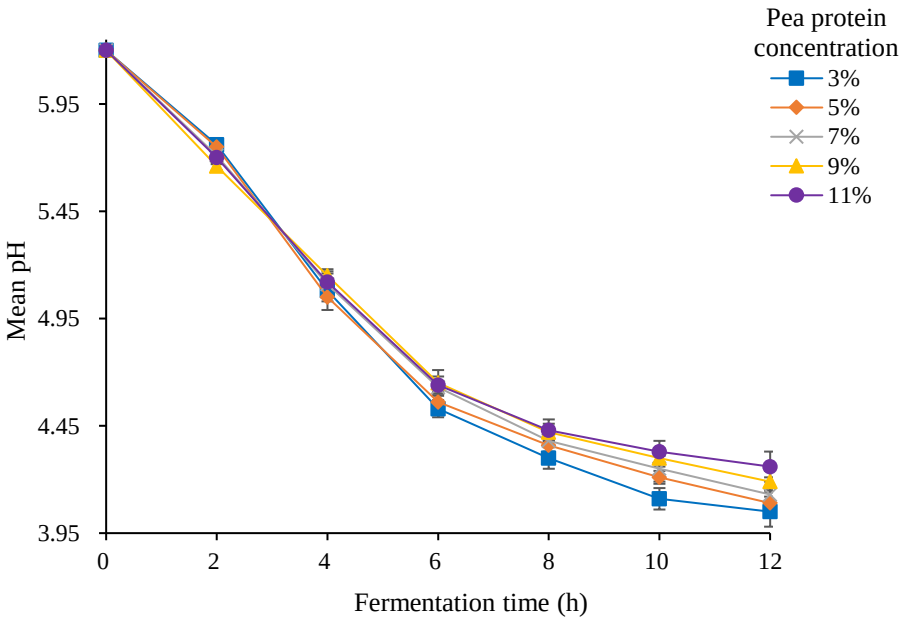



Figure 4.5 Mean pH of refined pea protein paste-coconut milk during fermentation by contained various pea protein concentrations

Notes: Error bars are means ± standard deviation; n=3.

The effect of the pea protein concentration on the decrease in pH can be mainly attributed to the metabolism of the sugar into organic acids in the fermentation mixture. The sugar content in pea protein is low, around 1-2% (Sánchez et al., 1998). Thus, the different pea protein

concentrations are likely to have a limited effect on pH change of the fermentation. In the present study, the fermentation was mostly induced by the sugar content of coconut milk.

Several studies have investigated the effects of different protein concentrations on the fermentations. Angelov et al. (2006) fermented a whole-grain oat substrate with lactic acid bacteria to produce a drink. Similar to our study, they found that lower concentrations (4.0–5.5%) of oat flour in the mash were more appropriate for intensive fermentation. Also, Denkova et al. (2015) used fermentation to produce a pea protein-cow milk yogurt. They found that the lower concentrations (2-4%) of pea protein in the yogurt had a faster rate of fermentation. In contrast, Mauro and Garcia (2019) reported higher concentration (1:3 w /v) of coconut pulp in water better for the growth of *Lactobacillus reuteri* LR 92 grown in coconut milk beverage.

In this experiment, the highest pH change (6.20±0.00 to 4.04±0.08) was obtained in the mixture containing 3% pea protein. Therefore, 3% pea protein concentration was selected for the subsequent experiments (4.2.1.3).

#### 4.2.1.3 Effect of fermentation time on viable cell counts

Fermentation time is one of the key factors affecting the overall characteristics of fermented beverages. It is therefore important to determine the optimum fermentation times to develop full-bodied beverages (Montel, Masson, & Talon, 1998). The VCCs in the 3% pea protein paste-coconut milk mixture were determined during fermentation for 24 h at 45 °C (Figure 4.6). The cell counts increased rapidly during the first 8 h, from 5.48±0.15 log CFU /mL to 8.63±0.25 log CFU /mL ($p<0.05$), and then remained stable up to 12 h. From 12 h to 24 h, the cell counts decreased rapidly to about 7 log CFU /mL ($p<0.05$) (Appendix E).

Previous studies reported similar growth trends of the LAB in plant base fermented beverages including soymilk (Tsangalis et al., 2002; Telang et al., 2010). During fermentation of soymilk at 37 °C for 24 h, the growth of *Lactobacillus acidophilus* increased from $4.67\times10^5$ CFU /mL to $1.99\times10^9$ CFU /mL in the first 12 h and then decreased. Tsangalis et al. (2002) reported rapid exponential growth of *bifidobacteria* in soymilk fermentation in the first 12 h at 37 °C, while, Chun et al. (2008) obtained the exponential growth phase in the first 6 h of soymilk fermentation at 37 °C using single or mixed cultures of *S. infantarius and Weissella* sp 4.

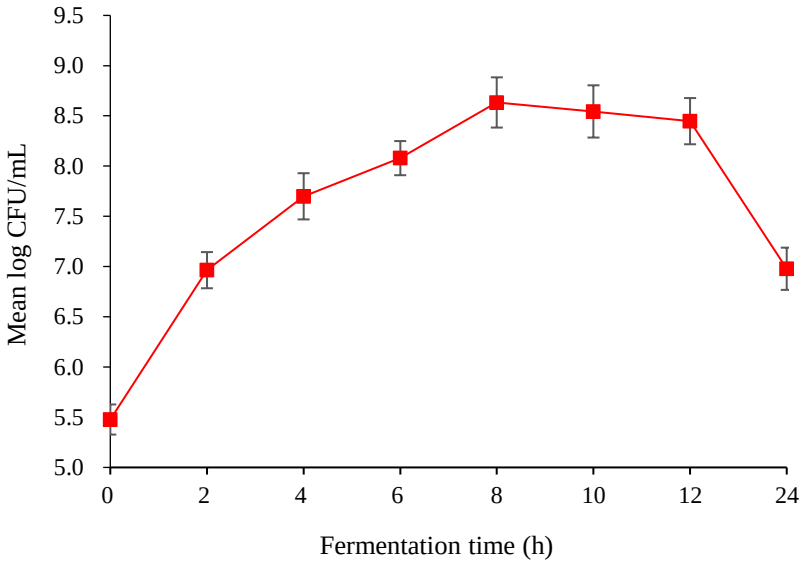



Figure 4.6 log CFU /mL of starter culture during fermentation of refined pea protein paste-coconut milk for 24 h at 45 °C

Notes: Error bars are means ± standard deviation; n=3.

In the present study, the highest VCCs were obtained at 8 h of fermentation and these remained stable up to 12 h (Pitt & Hocking, 2009). Thus, the three fermentation times (8, 10 and 12 h) which recorded the highest VCCs were used in the orthogonal test.

### 4.2.2 Selection (Optimisation) of the fermentation conditions

#### 4.2.2.1 Orthogonal test for bacterial growth

The fastest growth of starter culture was one of the criteria to design optimum fermentation conditions. Based on the previous single factor test results (Section 4.2.1), the experimental design in the first orthogonal test was a 3 x 3 x 3 factorial design with three fermentation temperatures (40 °C, 43 °C and 45 °C), three pea protein concentrations (3%, 5% and 7%) and three fermentation times (8, 10 and 12 h). There were 9 experimental samples under the 9 fermentation condition combinations. The response variable was the VCCs of the starter culture VEGE 053 LYO in each sample.

An L9 ($3^3$) orthogonal table and test results are shown in Table 4.1. Different fermentation combinations (experiments 1-9) produced different VCCs. The quantity of bacteria in the nine fermented pea protein-coconut milk beverages ranged from 8.00±0.28 log CFU /mL to

8.78±0.21 log CFU /mL. Sample 1, which contained 3% pea protein and fermented at 40 °C /8 h had the highest VCCs (8.78±0.21 log CFU /mL). While the cell counts of sample 9 were the lowest (8.00±0.28 log CFU /mL). Table 4.1 indicates that the optimum fermentation condition of the fermented pea protein-coconut milk beverage was A1B1C1 (k1> k2 and k3). It can be explained that 3% refined pea protein in the pea protein-coconut milk mixture fermented at 40 °C /8 h was the best fermentation condition for the bacteria growth (Table 4.1). The size of the ranges was $S_A > S_B > S_C$ (0.28>0.27>0.20). It revealed that fermentation temperature had the highest impact on the bacterial quantity of the culture. Meanwhile, pea protein concentration had the smallest effect on the VCCs of fermented pea protein-coconut milk beverage.

Table 4.1 Effects of temperature, time and protein concentration on the fermentation of refined pea protein paste-coconut milk using orthogonal test

| Experiments | Factor A (fermentation temperature) | Factor B (fermentation time) | Factor C (protein concentration) | Mean cell counts /log CFU /mL |
|---|---|---|---|---|
| 1 | 40 °C | 8 h | 3 % | 8.78±0.21 |
| 2 | 40 °C | 10 h | 5 % | 8.54±0.32 |
| 3 | 40 °C | 12 h | 7 % | 8.43±0.44 |
| 4 | 43 °C | 8 h | 5 % | 8.65±0.33 |
| 5 | 43 °C | 10 h | 7 % | 8.18±0.22 |
| 6 | 43 °C | 12 h | 3 % | 8.52±0.15 |
| 7 | 45 °C | 8 h | 7 % | 8.51±0.36 |
| 8 | 45 °C | 10 h | 3 % | 8.41±0.20 |
| 9 | 45 °C | 12 h | 5 % | 8.00±0.28 |
| $K_1$ | 25.75 | 25.94 | 25.71 | |
| $K_2$ | 25.35 | 25.14 | 25.20 | |
| $K_3$ | 24.92 | 25.11 | 25.11 | |
| $k_1$ | 8.58 | 8.65 | 8.57 | |
| $k_2$ | 8.45 | 8.38 | 8.40 | |
| $k_3$ | 8.31 | 8.37 | 8.37 | |
| S | 0.28 | 0.27 | 0.20 | |

Notes: Orthogonal design generated by SPSS Version 22 (IBM™, New York, USA) software.
K is the sum of mean cell counts (log CFU /mL) of the same level factors; k is the K divided by 3; S is the size of the range of k (Li, 2014; Deesuth et al., 2012; Khongsay et al., 2012).

According to Pereira, Maciel and Rodruiguez (2011), the growth of microorganisms depends on various factors, including the pH of the substrate, temperature and type of starter culture. As the present study, many previous studies (Li, 2014; Deesuth et al., 2012; Khongsay et al., 2012) have applied orthogonal design and data analysis methods to optimise fermentation conditions. Orthogonal tests have been used in various studies to optimise fermentation

conditions. Li (2010) used single-factor test and orthogonal test to optimise the culture conditions of *Saccharomy cescerevisiae.* Deesuth et al. (2012) and Khongsay et al. (2012) optimised the parameters for bioethanol production from sweet sorghum juice by *Saccharomyces cerevisiae* NP using an orthogonal array design. Statistical methods can provide a comprehensive and objective analysis of results (Mauro & Garcia, 2019; Meena et al., 2014).

#### 4.2.2.2 Sensory evaluation

The acceptability of food is an important reference indicator by consumers which affects new product development (Jarvis, MacKenzie & Podsakoff, 2003). Sensory evaluation was conducted by a semi-trained sensory panel (n=18) to evaluate and screen the 9 experimental samples (section 4.2.2.1) for the appearance, aroma, sourness, sweetness, mouthfeel, after-taste, beany flavour and overall acceptability. The semi-trained panellists used the 9-point hedonic rating scale on likability (Appendix E).

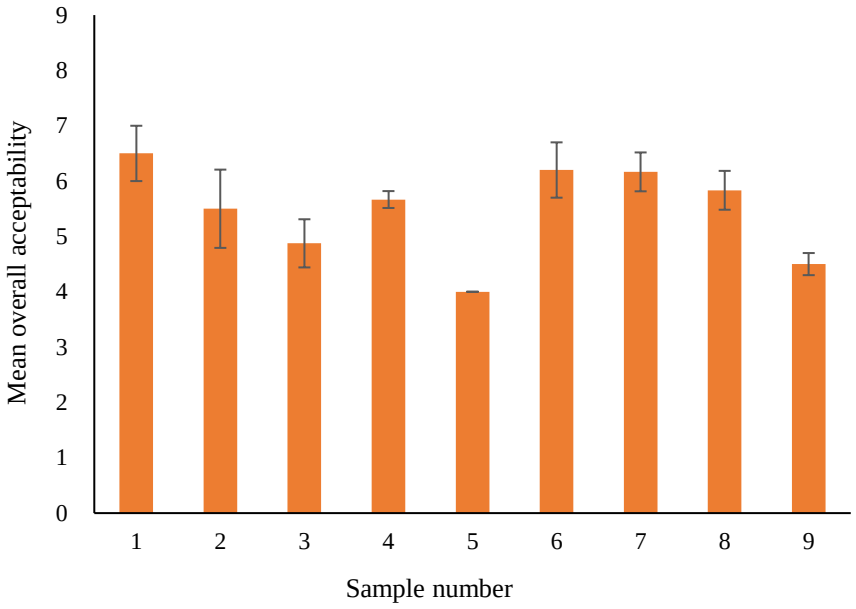



Figure 4.7 Mean sensory acceptability scores for the pea protein-coconut milk fermented milk

Notes: Hedonic scaling: 1-9 with 1 as lowest and 9 the highest; Error bars are means ± standard deviation, n=3.

Figure 4.7 shows the results of the sensory evaluation of 9 samples of fermented pea protein-coconut milk beverages. The overall acceptability scores for all the 9 samples ranged from 4.00±0.00 to 6.50±0.50 (Appendix E). Samples 1, 6 and 7 obtained higher scores ($p<0.05$) than

the other six samples (Figure 4.7). Sample 5 received the lowest mean acceptability sensory score (4.00±0.00), which contained 7% pea protein and was fermented at 43 °C /10 h. The characteristic beany flavour of the pea protein was not detected by the semi-trained sensory panel in all the samples. This suggested that fermentation was able to reduce or remove the beany flavour. However, the volatile compounds that cause the beany flavour in pea protein and related products were not analysed in this study. It is therefore desirable to analyse the compounds in future studies.

Results in Table 4.2 show that the optimum fermentation condition for fermented pea protein-coconut milk beverage was the fermented sample contained 3% pea protein in the fermentation mixture fermented at 40 °C /8 h and it received the highest overall sensory acceptability score (6.50±0.50).

Table 4.2 Effect of fermentation conditions on overall acceptability of fermented pea protein -coconut milk beverage

| Experiments | Factor A (fermentation temperature) | Factor B (fermentation time) | Factor C (protein concentration) | Mean semi-trained sensory panel sensory score |
|---|---|---|---|---|
| 1 | 40 °C | 8 h | 3 % | 6.50±0.50 |
| 2 | 40 °C | 10 h | 5 % | 5.50±0.50 |
| 3 | 40 °C | 12 h | 7 % | 4.67±0.15 |
| 4 | 43 °C | 8 h | 5 % | 5.67±0.15 |
| 5 | 43 °C | 10 h | 7 % | 4.00±0.00 |
| 6 | 43 °C | 12 h | 3 % | 6.20±0.50 |
| 7 | 45 °C | 8 h | 7 % | 6.17±0.35 |
| 8 | 45 °C | 10 h | 3 % | 5.83±0.35 |
| 9 | 45 °C | 12 h | 5 % | 4.50±0.20 |
| $K_1$ | 16.88 | 18.34 | 18.53 | |
| $K_2$ | 15.87 | 15.33 | 15.67 | |
| $K_3$ | 16.50 | 15.05 | 15.05 | |
| $k_1$ | 5.63 | 6.11 | 6.18 | |
| $k_2$ | 5.29 | 5.11 | 5.22 | |
| $k_3$ | 5.50 | 5.02 | 5.02 | |
| S | 0.34 | 1.10 | 1.16 | |

Notes: Orthogonal design generated by SPSS Version 22 (IBM™, New York, USA) software.
K is the sum of mean cell counts (log CFU /mL) of the same level factors; k is the K divided by 3; S is the size of the range of k (Li, 2014; Wang et al., 2010; Deesuth et al., 2012; Khongsay et al., 2012).

The size of the range was $S_C > S_B > S_A$ (1.16>1.10>0.34), which suggested that the pea protein concentration had the highest impact on the acceptability of the fermented pea protein-coconut

milk beverage. Whereas fermentation temperature has the lowest impact on the acceptability of the fermented pea protein-coconut milk beverage (Table 4.2).

### 4.2.3 Consumer sensory evaluation of fermented pea protein-coconut milk beverage during fermentation at 40 °C /8 h.

The purpose of the consumer sensory evaluation was to determine the acceptability of the three samples by a larger sensory group (n=90). Three samples (1, 6, 7; Table 4.2) which received the highest sensory scores for acceptability from the semi-trained sensory panel sensory evaluation were presented to consumer sensory panellists for evaluation in this section.

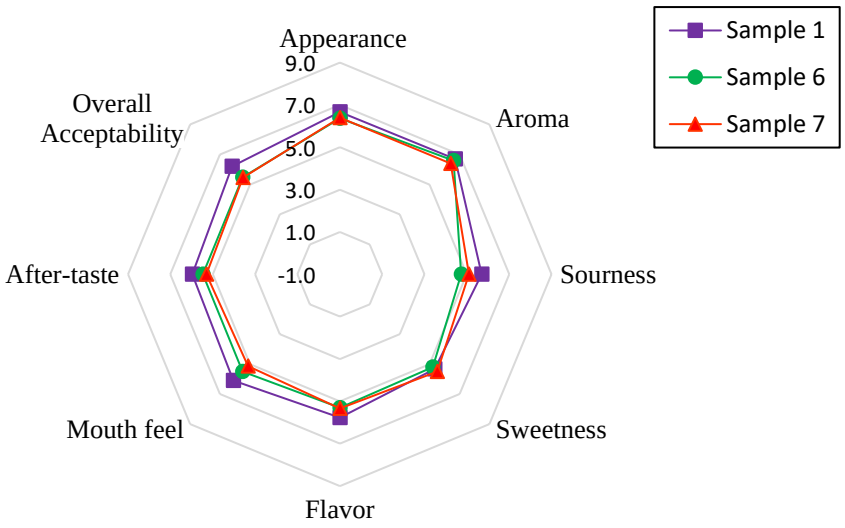



Figure 4.8 Mean sensory scores of fermented pea protein-coconut milk beverage

Notes: Sample 1 = contained 3% pea protein and was fermented at 40 °C /8 h; Sample 6 = contained 3% pea protein and was fermented at 43 °C /12 h; Sample 7 = contained 5% pea protein and was fermented at 45 °C /8 h; Hedonic scale: 1-9 with 1 as lowest and 9 highest; Error bars = ± SD; n=90.

The results of consumer sensory evaluation for appearance, aroma, sourness, sweetness, flavour, mouthfeel, after-taste and overall acceptability of the three fermented beverages are shown in Figure 4.8. The spider plot in Figure 4.8 shows that the different fermentation conditions had minimal effects on the sensory characteristics of the fermented beverage. Except for sweetness, the score of other characteristics of sample 1 were all higher than the accordance characteristics score of samples 6 and 7 ($p<0.05$) (Appendix E). Sample 1 received a higher

overall sensory score (6.2) than sample 6 and sample 7 which have the same overall sensory score (5.5). Therefore, it can be concluded that sample 1, which contained 3% pea protein and fermented at 40 °C /8 h was best accepted by the consumers. Sample 1 was therefore selected as the final fermented pea protein-coconut milk beverage (Figure 4.9). The optimum fermentation conditions (3% pea protein, 40 °C, 8 h) were used in the following section 4.2.4.

The bitter taste and beany flavour of the pea protein were not detected by the sensory panellist after the refined pea protein fermented with coconut milk. That could be attributed to the fermentation removed the beany /bitter flavour of pea protein.

Figure 4.9 Appearance of fresh final fermented pea protein-coconut milk beverage

Note: Image was captured by iPhone XR, Apple Inc., California, USA.

Several previous studies have analysed the sensory characteristics of plant-based fermented beverages. For example, Menezes et al. (2018) studied the fermentation of *Lactobacillus paracasei* LBC-81 in a maize-based substrate by a LAB-yeast co-culture. The overall sensory acceptability of their products ranged from 5.07 to 5.45, which were lower than the present study. In contrast, higher sensory acceptability scores (ranged from 7.28 to 7.8) were shown for a kefir grain fermented cocoa beverages (Puerari, Magalhães, & Schwan 2012). The differences in the scores of overall sensory acceptability might be attributed to the fermentation of Menezes et al. (2018) did not add flavours and sweetness.

Additionally, the general improvement of the sensory profile of fermented products by added culture has been widely reported (Kaczmarska et al., 2018; Meinlschmidt et al., 2016; Schindler

et al., 2011; Yaakob et al., 2012). According to Obinna-Echem, Kuri and Beal (2014) and Edema and Sanni (2008), the use of starter cultures improved the aroma of fermented maize due to the release of aromatic compounds. They also indicated the added starter culture produced a better flavour and aroma profile.

### 4.2.4 Characteristics of pea protein-coconut milk fermentation during fermented at 40 °C /8 h

#### 4.2.4.1 Acidity

The acidity (pH and T.A.) of fermented pea protein-coconut milk beverage was determined during fermentation for at 40 °C /8 h (Figures 4.10). The pH of fermented pea protein-coconut milk beverage decreased from 6.15±0.13 to 4.29±0.02, while T.A. increased ($p<0.01$) steadily from 0.09%±0.01 to 0.52%±0.03 during fermentation ($p<0.05$) (Appendix E).

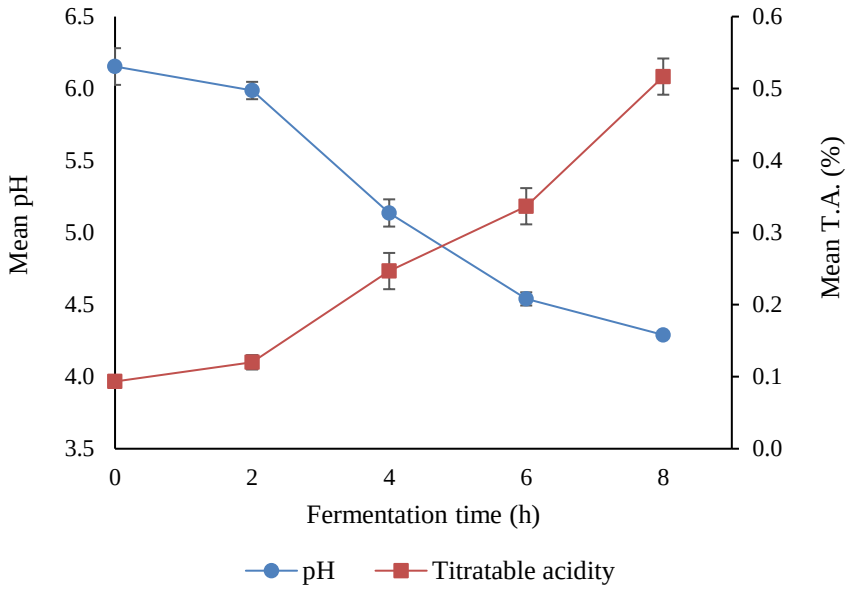



Figure 4.10 Mean pH and titratable acid of fermented pea protein-coconut milk beverage during fermentation at 40 °C /8 h

Notes: T.A. = Titratable Acidity; Error bars are means ± standard deviation; n=3.

Our results are similar to previous studies by Garcia et al. (2006) and Sabokbar and Khodaiyan (2015). Fermentation of plant-based beverages produces organic acids such as lactic acid and acetic acid (Stadie et al., 2013; Laureys & De Vuyst, 2014). The concomitant increase in T.A. and decrease in pH may be attributed to the metabolism of sugars in fermented pea protein-

coconut milk beverages to organic acids by LAB via either the homofermentative and heterofermentative pathways or the fructose-6-phosphate phosphoketolase pathway (Hamad, 2011; Mauro & Garcia, 2019).

The pattern of changes in pH and titratable acidity (T.A.) differ according to the type of microorganism used and different fermentation conditions. The amount of acid produced in fermented beverages is dependent on the growth of bacteria or the type of starter culture used (Kazakos et al., 2016; Puerari et al., 2012). Mauro and Garcia (2019) studied the fermentation of coconut milk fermented by *L. reuteri* LR 92 or DSM 17938. Coconut milk was fermented with *L. reuteri* DSM 17938 to pH 3.32, while that fermented by *L. reuteri* LR 92 had pH 4.28 after 48 h at 37 °C. Donkor et al. (2007) reported a progressive decrease in pH and increased acidity during 48 h fermentation of soy yogurt, which was similar to the results observed in the present study. Zare et al. (2012) suggested that the development of acidity might be influenced by the carbohydrate content of the components added. The carbohydrate (concentration 6.34%) in coconut milk may assist the development of acidity during the fermentation.

#### 4.2.4.2 Viable cell counts

The growth of the starter bacteria VEGE 053 LYO during 8 h fermentation is shown in Figure 4.11. During fermentation, the bacteria exhibited steady growth, with the viable cell count increasing from 5.54±0.10 to 8.61±0.35 log CFU /mL ($p<0.05$) (Appendix E).

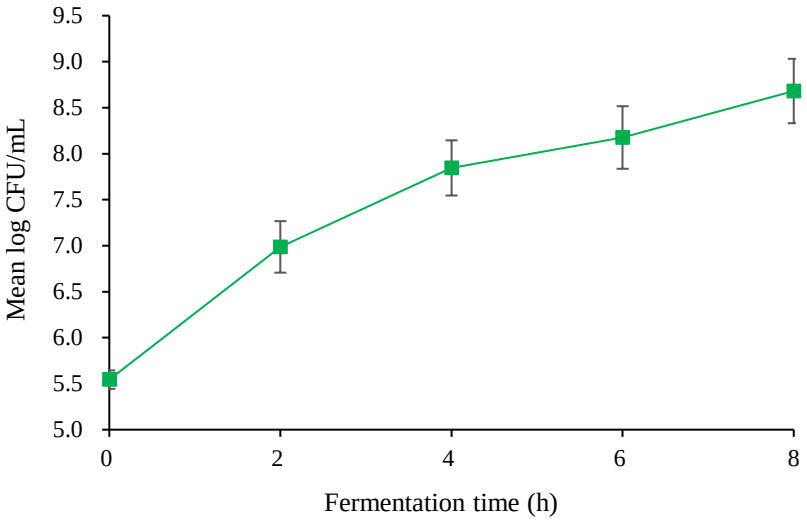


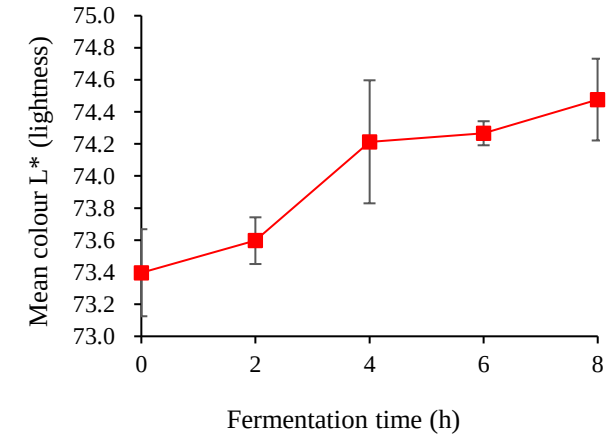

Figure 4.11 Mean VCCs (log CFU /mL) of fermented pea protein-coconut milk beverage during fermentation at 40 °C /8 h

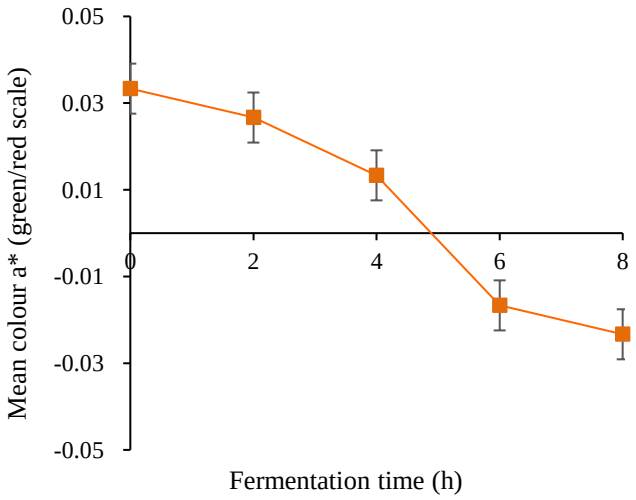
Notes: Error bars are means ± standard deviation; n=3.

Telang et al. (2010) and Stadie et al. (2013) reported similar results on VCCs to our study. To reduce the beany flavor of soymilk and obtain a nutritious food product, Telang et al. (2010) used LAB starter culture to ferment the soymilk. Viable cell counts of $10^9$ CFU /mL sample were obtained in the soymilk after 12 h of fermentation at 40 °C.

#### 4.2.4.3 Colour

Color is an important attribute of the dairy alternative beverages (Chaturvedula & Prakash, 2011; Pathare et al., 2013). Therefore, it was important to measure the color of the fermented pea protein-coconut milk beverage.



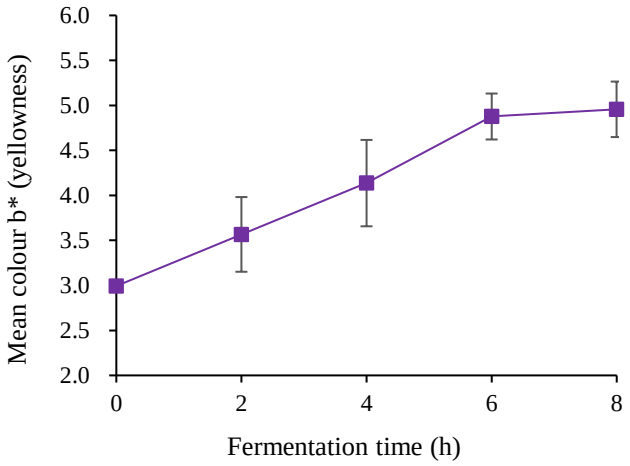



Figure 4.12 Mean L*, a*, b* values of fermented pea protein-coconut milk beverage during fermentation at 40 °C /8 h

Notes: Error bars are means ± standard deviation; n=3. L* represents lightness (0 is black and 100 is diffuse white); a* is the greenness /redness (negative values represent green, positive values represent red) and b* is the blue /yellow (negative values indicate blue, positive values are yellow) (Alqahtani, Aljurais, & Alshaafi, 2012).

As shown in Figure 4.12, the Hunter values (L*, a*, b*) of the fermented pea protein-coconut milk beverage transformed during fermentation ($p<0.05$). The L* and b* values increased during fermentation from 73.40±0.27 to 74.48±0.26 and 2.98±0.04 to 4.96±0.31, respectively, while a* value decreased from 0.03±0.01 to -0.02±0.01. The increasing L* value indicated that the color of the product became lighter, which was probably due to the suppression of ionization or destruction of the pigmented structure of the origins during the fermentation (Haslam, 2003).

Schaffner and Beuchat (1986) used *Streptococcus thermophilus* and *Lactobacillus bulgaricus* to ferment seed extract powder of soy flour, cowpea and peanut. The results showed that fermentation improved the color of the legume powders. But fermentation did not significantly impact the b* values for any of the legume products in their study.

4.2.4.4 Sugars and organic acids in fermented pea protein-coconut milk beverage

The levels of sugars and organic acids in the fermented pea protein-coconut milk beverage during fermentation are shown in Figure 4.13. Sucrose decreased from 2.20±0.06% to 1.83±0.04% during fermentation ($p<0.05$) (Appendix E). This result was similar to the study by Menezes et al. (2018) showed that sucrose was consumed during the fermentation of maize-based beverages. Glucose was not detected in the fermented pea protein-coconut milk beverage,

possibly because it was metabolism to lactic acid by the LAB culture. The concentration of fructose increased from 0.14±0.01% to 0.19±0.01% after pea protein-coconut beverage fermentation ($p<0.05$). Fructose increased during fermentation, suggesting that the monosaccharide was produced from the degradation of sucrose by lactic acid bacteria (Laurey & de Vuyst, 2014; Leroi & Pidoux, 1993). The increase in fructose was also reported by Stadie et al. (2013) during water kefir fermentation.

Lactic and acetic acid concentrations increased during 8 h fermentation ($p<0.05$) (Figure 4.13), which peaked at 1.23±0.09% and 2.79±0.953% respectively, by the end of fermentation. However, in the study of Menezes et al. (2018), the concentration of acetic acid ranged from 0.1 to 0.2 g /L, which was lower than the present study. The difference in the concentrations of acetic acid between two studies may be related to the variations of microflora composition in start culture and substrate (Hsieh et al., 2012). Production of lactic acid and acetic acid in dairy-free fermentations indicate the existence of homo-fermentative and hetero-fermentative pathways by LAB (Puerari et al., 2012; Stadie et al., 2013).

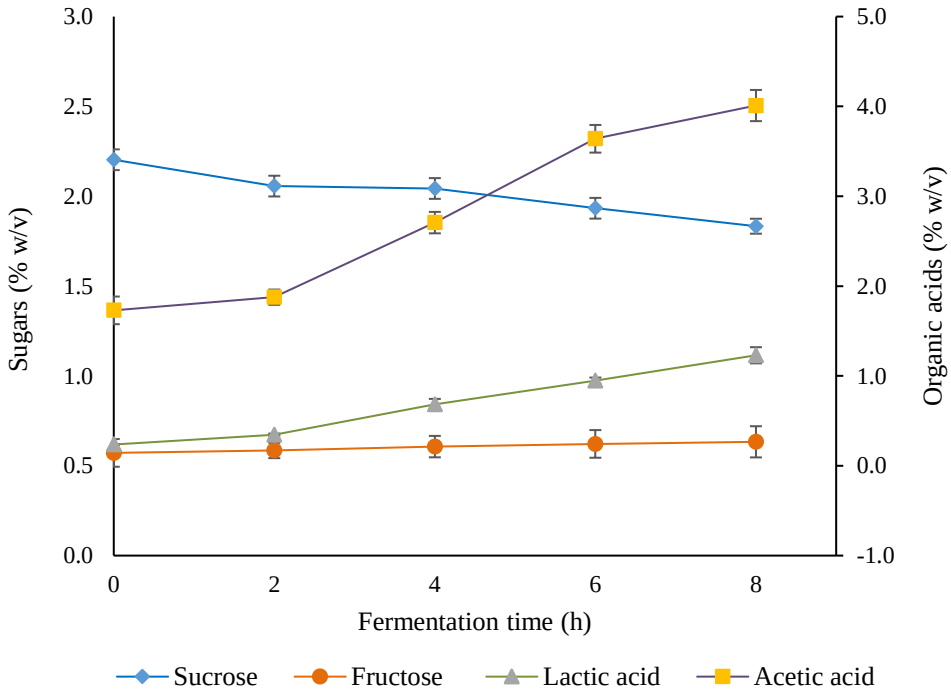



Figure 4.13 Concentrations of sugars and organic acids during the fermentation of fermented pea protein-coconut milk beverage at 40 °C /8 h

Notes: Error bars are means ± standard deviation; n=3.

#### 4.2.4.5 Protein content

There was no significant difference in the protein content of fermented pea protein-coconut milk beverage during fermentation ($p>0.05$). Khetarpaul and Chauhan (1989) reported similar results of crude protein in pearl millet flour during fermentation at 30 ℃ /72 h. The increased protein catabolism by fermenting microorganisms may account for the loss of protein through ammonia (a byproduct of metabolic deamination) (Assohoun et al., 2013). Our results are contrary to Magalhães et al. (2011) who reported an increase in protein content in Brazilian kefir. Shekib (1994) also reported an increase in the crude protein of fermented lentils and chickpea during fermentation.

### 4.2.5 Summary

There is an information gap in the optimisation of fermentation techniques for the growth and development of probiotic bacteria in plant-based products (Gupta & Abu-Ghannam, 2012). Results from phase 2 suggested that higher fermentation temperatures (40 °C, 43 °C and 45 °C), lower pea protein concentrations (3%, 5% and 7%), and three fermentation times (8, 10 and 12 h) improved the pea protein-coconut milk fermented by VEGE 053 LYO starter culture. Further, fermentation of pea protein-coconut milk containing 3% pea protein concentration at 40 °C /8 h was the most promising formulation for the fermented beverage (Sample 1). This beverage sample contained the highest quantity of VCCs (8.78 Log CFU /mL) and received the highest overall acceptability score of 6.2.

The pH, titratable acidity, VCCs, and colour changed during the fermentation of refined pea protein paste-coconut milk beverage ($p<0.05$). The protein content of the beverage was stable during fermentation.

## 4.3 Phase 3: Stability of the fermented pea protein-coconut milk beverage during storage at 4 °C /21 days.

### 4.3.1 The pH and titratable acid changes of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

Results of the pH and titratable acidity (T.A.%) of the fermented pea protein-coconut milk beverage stored at 4 °C for 21 days are presented in Figure 4.14. As expected, the pH of the fermented pea protein-coconut milk beverage decreased from day 1 to day 14 ($p<0.05$). However, the pH was stable from day 14 to day 21 ($p>0.05$). Titratable acidity increased ($p<0.05$) from day 1 to day 14 and remained stable during the last week of storage（$p>0.05$）(Appendix E).

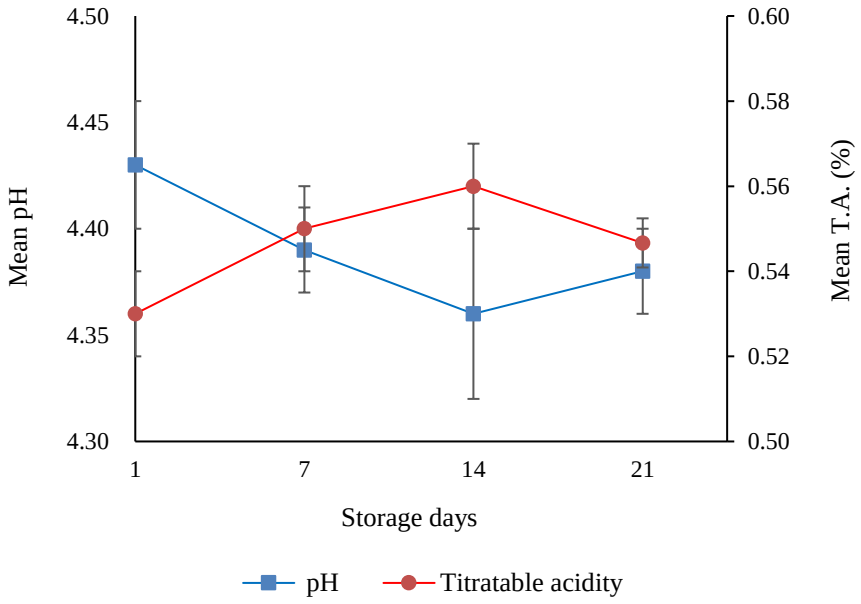



Figure 4.14 Mean pH and titratable acid of fermented pea protein-coconut milk beverage during the storage (4 °C) /21 days

Notes: T.A. = Titratable Acidity; Error bars are means ± standard deviation; n=3.

The acidity levels reported here are similar to the study by Akin and Ozcan (2017) who reported a decrease in pH (pH 4.33 to 3.95) during storage for 21 days /4 °C of a fermented pea protein-coconut milk beverage. Du (2018), also reported decreases in pH of berry-containing kefir during 28 days /4 °C. The reduction in pH suggested the continued metabolism of sugars to organic acids by the starter culture during storage (Yilmaz et al., 2006; Leite et al., 2013).

However, during the last seven days (day 14 to day 21), both pH and T.A. were stable probably due to lack of fermentable sugars.

### 4.3.2 Bacterial content of fermented pea protein-coconut milk beverage during storage for 21 days /4 °C

The viable cell counts of the LAB starter culture bacteria in the fermented pea protein-coconut milk beverage during storage are presented in Figure 4.15. The viable cells of the starter culture in the fermented pea protein-coconut milk beverage increased ($p<0.05$) from 8.66±0.04 log CFU /mL to 8.72±0.03 log CFU /mL during the first 14 days of storage, but decreased ($p>0.05$) to 8.70±0.02 log CFU /mL over the last seven days (Appendix E). Probiotic products should contain at least $10^6$ CFU /mL or gram at the time of consumption to confer health benefits to the consumer (Kechagia et al. 2013; Hill et al. 2014). Therefore, the cell counts in our cultured beverage met the recommended concentration of probiotic bacteria.

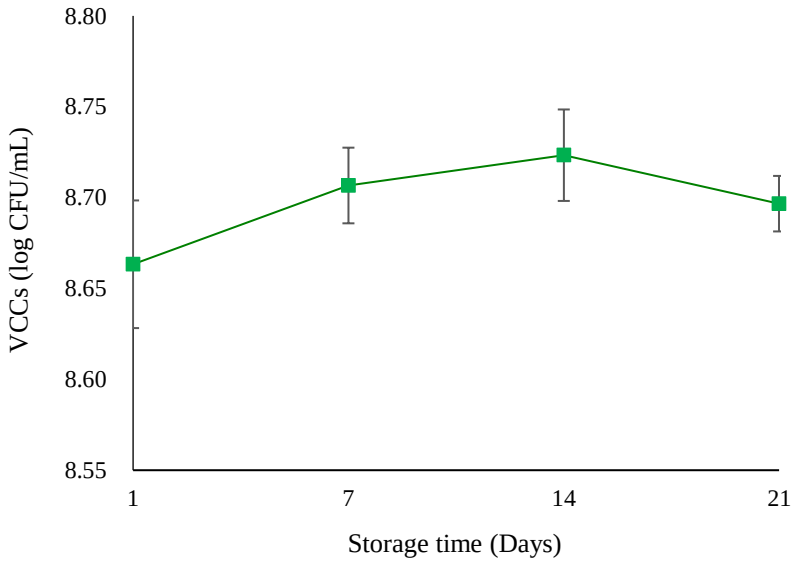



Figure 4.15 Mean VCCs (log CFU /mL) of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

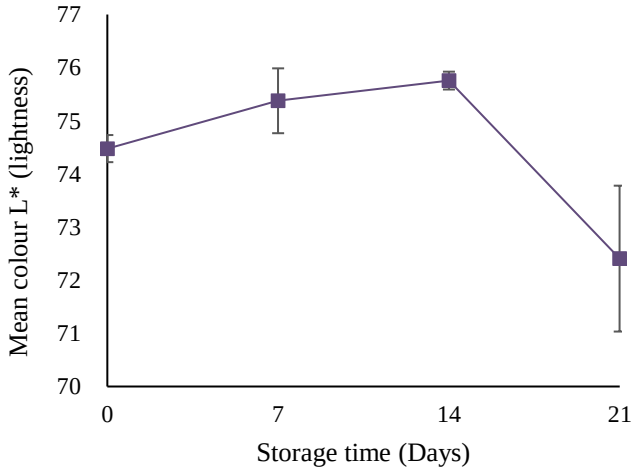
Notes: Error bars are means ± standard deviation; n=3.

Viable cell counts of the starter culture in the fermented beverage during storage may be affected by factors such as type of strains, substrate and storage temperature. Legumes contain complex carbohydrates (fiber, long-lasting starch and oligosaccharide) which contain growth factors and prebiotic components (Miller et al. 2000). Such growth factors and prebiotic

ingredients can promote the growth of the starter culture in the fermented beverage during storage. The decline in VCCs of the fermented beverage during storage was similar to other studies (Mauro & Garcia, 2019; Kazakos et al., 2016). The decrease in cell counts could be to the lack of nutrients after storage for 14 days which affected the continued growth of the microorganisms. It is well-documented that the accumulation of metabolic products such as lactic acid can inhibit the growth or survival of the LAB (Archbold et al., 2010; Costa et al., 2017; Miller et al. 2000). Several studies have shown a decrease in LAB in fermented products during storage (Costa et al., 2017; Santos et al., 2014; Freire et al., 2017). Costa et al. (2017) observed a decrease from $10^6$ to $10^5$ and $10^4$ CFU /g after 28 days of storage for *L. acidophilus* and *Bifidobacterium* spp. cells, respectively, in beverages produced from soya and rice by-products.

### 4.3.3 Colour of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

The colour of the fermented pea protein-coconut milk beverages during storage were measured in Hunter L*, a* and b* values (Figure 4.16). The lightness (L*) increased from 74.48±0.26 (day 1) to 75.76±0.17 (day 14) and then decreased to 72.41±1.37 at day 21 ($p<0.05$). The redness (a*) of fermented pea protein-coconut milk beverage was stable during the first week of storage, then increased from -0.17±0.11 to 0.38±0.07 from days 7 to 21 ($p<0.05$). The yellowness (b*) of fermented beverage increased from 4.96±0.31 to 5.17±0.44 in the first 7 days and then decreased to 4.16±0.23 during the last 14 days of refrigerated storage ($p<0.05$) (Appendix E).



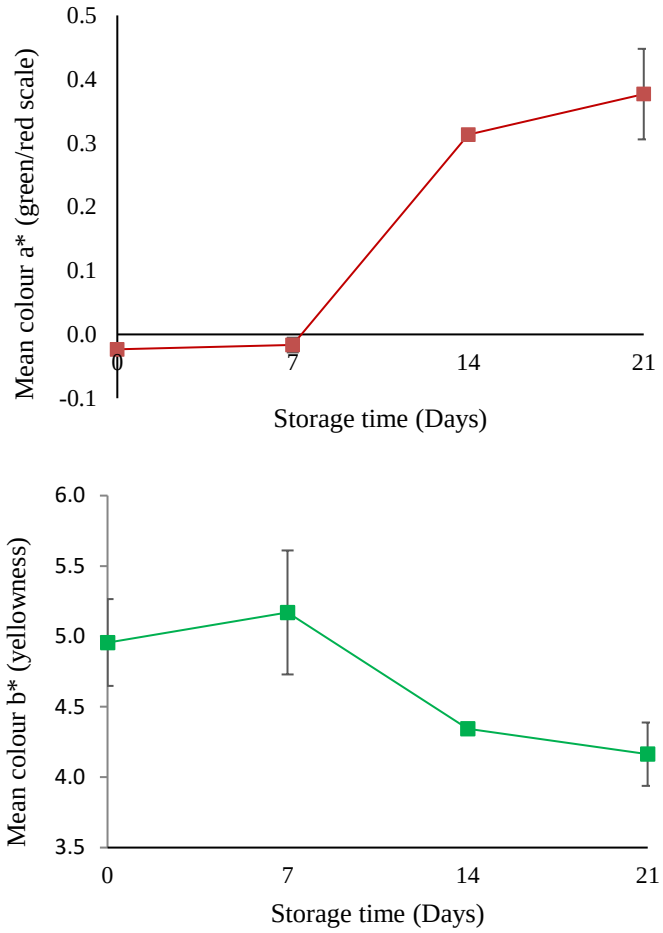



Figure 4.16 Mean colour values of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

Notes: Error bars are means ± standard deviation; n=3. L* represents lightness (0 is black and 100 is diffuse white); a* is the greenness /redness (negative values represent green, positive values represent red) and b* is the blue /yellow (negative values indicate blue, positive values are yellow) (Alqahtani, Aljurais, & Alshaafi, 2012).

In the study by Akin & Ozcan (2017), the yellowness (b*) of the fermented plant protein beverage decreased significantly ($p<0.05$) during storage for 21days. Hrnjez et al. (2014) also reported similar results during storage of fermented milk inoculated with a mixed LAB-yeast starter culture. The results of these two studies were similar to our results. The lightness of our pea protein-coconut fermented beverage was similar to the results reported by Zare et al. (2013). In our study, the lightness of the fermented beverage increased in the first two weeks during storage (4 °C) which was similar to the probiotic milk supplemented with pea flour reported by Zare et al. (2013). The redness (a*) of our fermented beverage changed during storage ($p<0.05$), whereas the redness of plant-based fermented milk produced by Akin and Ozcan (2017) was stable. The discrepancies in the results of redness of fermented beverages during storage may be attributed to the different protein sources and protein concentrations used.

### 4.3.4 Changes in sugar and organic acid levels in fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

The sucrose concentration in fermented pea protein-coconut milk beverage decreased from 3.65±0.03% to 1.68±0.01% ($p<0.05$) (Appendix E), whereas fructose did not change during storage for 21 days /4 ℃. (Figure 4.17). The decrease in sucrose levels was expected as the disaccharide is hydrolysed to glucose and fructose moieties by the enzyme invertase, which is metabolised by the fermenting LAB culture (Stadie et al., 2013).

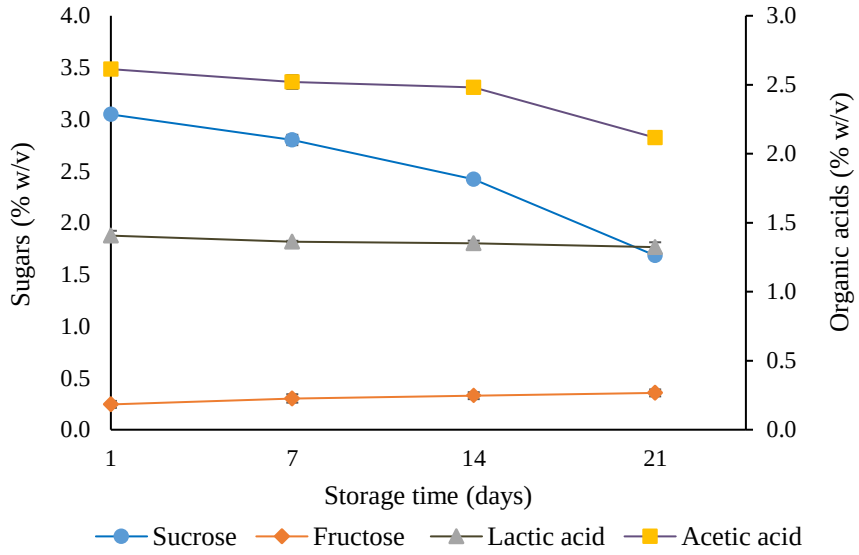



Figure 4.17 Concentrations of sugars and organic acids in fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

Notes: Error bars are means ± standard deviation; n=3.

Acetic acid and lactic acid steadily decreased from 2.61±0.03% to 2.12±0.01% and from 1.41±0.04% to 1.32±0.04% (w /v) respectively during refrigerated storage for 21 days ($p<0.05$) (Figure 4.17). Menezes et al. (2018) reported similar reductions of lactic and acetic acids during storage of maize-based beverage stored for 28 days at 4 ℃. The decreases in lactic acid observed during storage in our study and previous work may result from the metabolism of lactic acid to pyruvic acid, ethanol and $CO_2$ (Paucean et al., 2012). The reduction of organic acids, mainly acetic acid, is considered to be a positive factor (Menezes et al., 2018) because at high concentrations acetic acid (>0.34 g /L) may provide off-flavours.

### 4.3.5 Protein content of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

There was no change in protein concentration of the fermented pea protein-coconut milk beverage during storage for 21 days /4 °C (Appendix E). Peng et al. (2009) and Lucey (2001) also reported stable protein content of plant protein beverage products during storage.

### 4.3.6 Changes in sensory characteristics of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

Results of the semi-trained sensory panel (n=15) sensory evaluation of fermented pea protein-coconut milk beverage during storage are shown in Figure 4.18. The scores for appearance, sourness, flavor, mouthfeel and after-taste were changed significantly during 21 days, 4 °C storage ($p<0.05$). However, mean sensory scores for aroma, sweetness and overall acceptability were stable ($p>0.05$). The scores for overall acceptability slightly decreased from 6.8±0.40 (day 1) to 6.2±0.20 (day 21) ($p>0.05$). Thus, the products were slightly like by the panelists on day 21 (Appendix E). The results of the sensory evaluation suggest that although some sensory properties changed during the three weeks cold-storage (4 °C), the fermented pea protein-coconut milk beverage still accepted by the consumers.

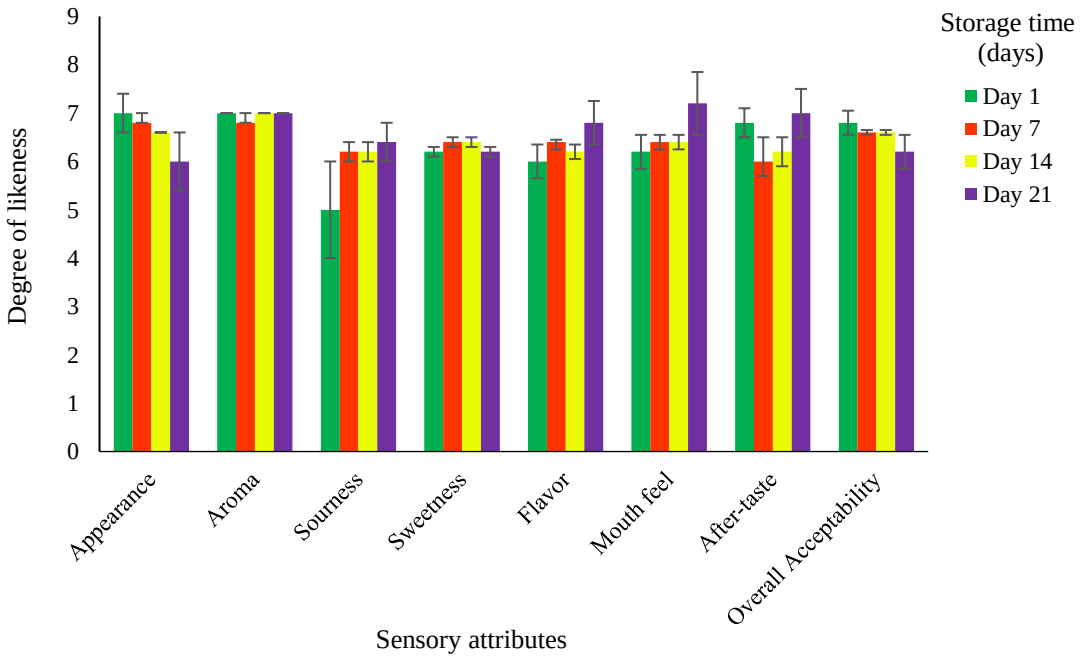


Figure 4.18 Mean training group sensory evaluation scores of fermented pea protein-coconut milk beverage during the storage time

Notes: Error bars are means ± standard deviation; n=3; A 9-point hedonic scale with descriptive anchors was used to evaluate each parameter (1= dislike extremely; 9 = like extremely)

The results of the sensory evaluation were similar to those reported by Kilic et al. (1999) who reported no significant effects of storage (4 °C) for 21 days on the sensory attributes of milk yogurt with plant proteins, but the overall acceptability decreased. Awobusuyi (2015) reported improved stability of a non-alcoholic fermented cereal beverage during storage. The samples of the fermented cereal beverage were more accepted at 5 days of storage.

### 4.3.7 Summary

Phase 3 monitored the change of pH, titratable acidity (T.A.), viable cell counts (VCCs), colour, sugars, organic acid, protein content and sensory characteristics of the fermented pea protein-coconut milk beverage during the 21 days storage (4 °C). The values of pH, T.A., VCCs, color, sugar and organic acid all had significant changes during the storage period ($p<0.05$). And the beverage product was well-liked by the sensory consumer panelists on using a hedonic rating scale. These results confirmed that although the physical-chemical properties of fermented pea protein-coconut milk beverage changed during the storage period, the beverage still can be store 21 days without loss sensory acceptability characteristics.

# 5. OVERALL CONCLUSION

The purification methods used in this study was successful in transforming the yellow commercial pea protein powder into a white paste. On a dry basis, the protein concentration of the refined pea protein paste increased by 15% compared with the commercial pea protein powder after the extraction process due to the protein enrichment. The treatment of pea protein-coconut milk containing 3% pea protein produced the most acceptable fermented beverage by a consumer panel. The beverage was characterized by high viable cell counts of the starter culture used and was stable during storage for 21 days at 4 ℃. The beany flavour of the pea protein was not detected by the sensory panellists after fermentation of the refined pea protein-coconut milk beverage and during storage.

# 6. RECOMMENDATIONS

The following recommendations are suggested for future research:

The white refined pea protein paste may be used as a source of protein supplement in high protein food products such as pea protein biscuit, pea protein-plant milk beverage and pea protein-dairy yoghurt.

Gas chromatography-mass spectrometry analysis of the organic compounds which are responsible for the bitter and beany flavors is desirable.

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# APPENDICES

## Appendix A. Composition of agar media and its ingredient for microbiological analyses

| Product name and Brand | Ingredients | Composition (g) |
|---|---|---|
| MRS agar (CM0361), Oxoid | Pepton | 10 |
| | Lab-Lemco powder | 8 |
| | Yeast extract | 4 |
| | Hydrogen phosphate | 2 |
| | Sodium acetate 3H2O | 5 |
| | Tri-ammonium citrate | 2 |
| | Magnesium sulphate 7H2O | 0.2 |
| | Manganese sulphate 4H2O | 0.05 |
| | Agar | 10 |
| M17 agar (CM0785), Oxoid | Tryptone | 5 |
| | Soya peptone | 5 |
| | Meat digest | 5 |
| | Yeast extract | 2.5 |
| | Ascorbic acid | 0.5 |
| | Magnesium sulphate | 0.25 |
| | di-sodium-β-glycerophosphate | 19 |
| | Agar | 11 |

**Appendix B. Sensory evaluation questionnaire, participant information sheet and consent form**

SENSORY EVALUATION QUESTIONNAIRE

Panelist Number:
Date:

Please evaluate the product given to you by selecting (√) the attribute that best describes your feelings about the respective property of the product. You will be provided with three samples to taste. Please rinse your mouth with water before and between samples.

Sample Code:

| Attribute | Dislike extremely | Dislike very much | Dislike moderately | Dislike slightly | Neither like nor dislike | Like slightly | Like moderately | Like very much | Like extremely |
|---|---|---|---|---|---|---|---|---|---|
| Appearance | | | | | | | | | |
| Aroma | | | | | | | | | |
| Sourness | | | | | | | | | |
| Sweetness | | | | | | | | | |
| Flavour | | | | | | | | | |
| Mouth feel | | | | | | | | | |
| After-taste | | | | | | | | | |
| Overall Acceptability | | | | | | | | | |

Comment:

PARTICIPANT INFORMATION SHEET

Study title: Consumer sensory evaluation of fermented coconut beverage containing pea protein

Location: Massey University, Auckland. Ethics committee ref. 4000020456
Researcher: Qu Weidi (Master student) E-mail: quweidivicky@gmail.com
Supervisor: Dr Tony Mutukumira E-mail: A.N.Mutukumira@massey.ac.nz
Associate Supervisor: Dr Kay Rutherfurd E-mail: k.j.Rutherfurd@massey.ac.nz

Introduction

This study is a part of my research project and may contribute to the development of fermented coconut–pea protein beverage. You are being invited to participate in the evaluation of the sensory characteristics of this beverage. The aim of the sensory evaluation is to determine the level of likeness of the beverages and their acceptance.

Participant involvement

The trial involves tasting three types of coconut–pea protein beverages. Your participation will take around 5 minutes. The three types of beverages you will taste may contain all or some of following ingredients: commercial pea protein powder (Roquette S85F), commercial organic coconut milk (Ceres Organics), commercial start culture (Dupont VEGE 053).

You should not take part if you are allergic or may be affected by the consumption of any of the listed ingredients. In the unlikely event of any adverse reaction, medical assistance will be provided. You may advise one of the researchers of any potentially relevant cultural, religious or ethical beliefs which may prevent you from consuming the foods under consideration.

The information collected in this study will not be linked to any individual's identity and will be only used to complete the research project. Should you wish to receive a summary of the findings once data analysis has been completed, please provide your contact email address or phone number.

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular questions;
- Withdraw from the study (at any time);
- Ask any questions about the study at any time during participation;
- Provide information on the understanding that your name will not be used unless you give permission to the researcher;

"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email humanethics@massey.ac.nz".

## PARTICIPANT CONSENT FORM

I have read and understood the Participant Information Sheet.

I agree to take part in this project.

I have been given the opportunity to ask questions and I am satisfied with the responses.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason.

Declaration by participant:

I hereby consent to take part in this study.

Participant's name: Panelist Number:

Signature: Date:

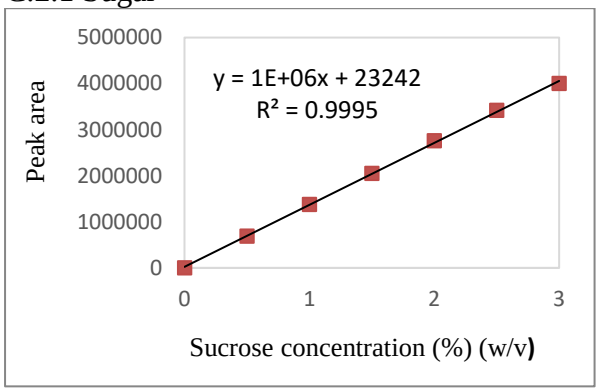
## Appendix C. HPLC data results

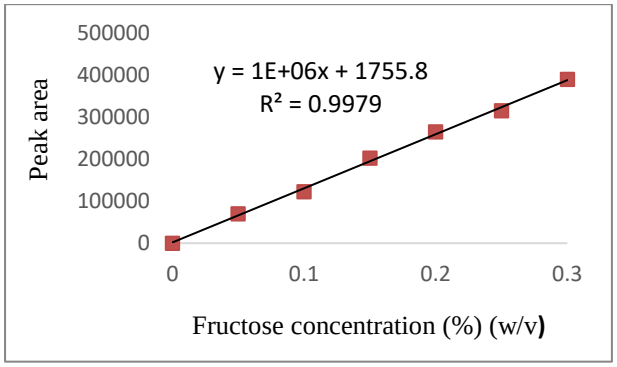
C.1 HPLC data results for sugar and organic acids standard peak area and retention time

| Standards | Concentration (%) (w /v) | Mean peak area | Mean retention time (minutes) |
|---|---|---|---|
| Sucrose | 0.50 | 689602 | 9.026 |
| | 1.00 | 1374955 | |
| | 1.50 | 2050978 | |
| | 2.00 | 2754818 | |
| | 2.50 | 3414687 | |
| | 3.00 | 3999856 | |
| Fructose | 0.05 | 70289 | 13.418 |
| | 0.10 | 122467 | |
| | 0.15 | 202530 | |
| | 0.20 | 265223 | |
| | 0.25 | 315695 | |
| | 0.30 | 390990 | |
| Lactic acid | 0.3125 | 2394658 | 17.564 |
| | 0.6250 | 4782754 | |
| | 1.2500 | 9433185 | |
| | 2.5000 | 19781525 | |
| | 5.0000 | 39610808 | |
| Acetic acid | 0.3125 | 2588825 | 20.178 |
| | 0.6250 | 5156965 | |
| | 1.2500 | 11022641 | |
| | 2.5000 | 24023412 | |
| | 5.0000 | 46932663 | |

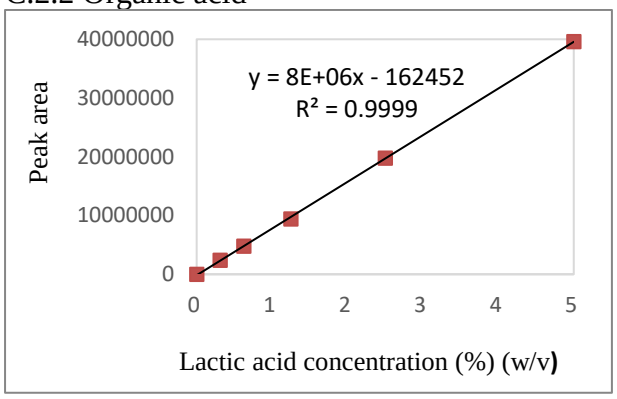
## C.2 Standard curves

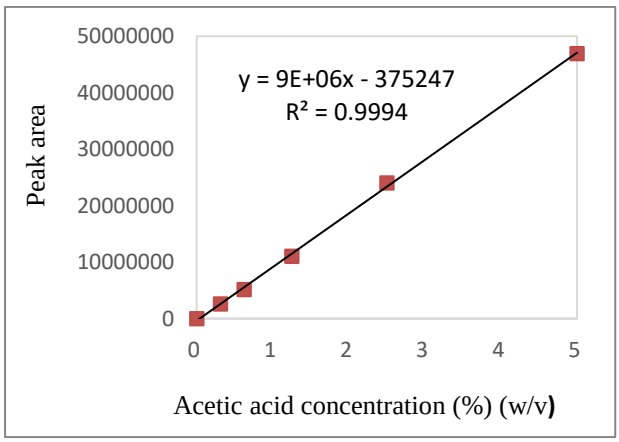
### C.2.1 Sugar




### C.2.2 Organic acid



## Appendix D. Raw data

### D.1 Raw data phase 1: Commercial pea protein powder purification

D.1.1 Description of colour of refined commercial pea protein powder

| Colour | Replication | L* | a* | b* |
|---|---|---|---|---|
| Commercial pea protein powder | 1 | 76.76 | +3.09 | +16.23 |
| | 2 | 76.97 | +3.09 | +16.33 |
| | 3 | 76.92 | +3.06 | +16.41 |
| Refined pea protein paste | 1 | 81.49 | +0.42 | +6.77 |
| | 2 | 81.67 | +0.30 | +6.99 |
| | 3 | 80.27 | +0.33 | +6.82 |

D.1.2 Protein content of refined pea protein

| Protein | Replication | Nitrogen % | Protein % |
|---|---|---|---|
| Commercial pea protein powder | 1 | 12.48 | 78.00 |
| | 2 | 12.30 | 76.88 |
| | 3 | 12.39 | 77.44 |
| Refining pea protein paste | 1 | 2.77 | 17.31 |
| | 2 | 2.82 | 17.63 |
| | 3 | 2.72 | 16.99 |
| Refining pea protein paste (dry matter) | 1 | 14.70 | 91.87 |
| | 2 | 15.08 | 94.24 |
| | 3 | 18.84 | 92.78 |

## D.2 Raw data phase 2: Development of fermented pea protein-coconut milk beverage

D.2.1 The pH of coconut milk fermentation by different temperatures

| Time (h) | Replication | pH (35 °C) | pH (37 °C) | pH (40 °C) | pH (43 °C) | pH (45 °C) |
|---|---|---|---|---|---|---|
| 0 | 1 | 6.20 | 6.20 | 6.20 | 6.20 | 6.20 |
| 0 | 2 | 6.20 | 6.20 | 6.20 | 6.20 | 6.20 |
| 0 | 3 | 6.20 | 6.20 | 6.20 | 6.20 | 6.20 |
| 2 | 1 | 6.09 | 6.03 | 5.75 | 5.71 | 5.62 |
| 2 | 2 | 6.12 | 6.05 | 5.79 | 5.73 | 5.66 |
| 2 | 3 | 6.06 | 6.01 | 5.71 | 5.69 | 5.58 |
| 4 | 1 | 5.21 | 5.15 | 5.05 | 4.57 | 4.55 |
| 4 | 2 | 5.26 | 5.21 | 5.10 | 4.65 | 4.60 |
| 4 | 3 | 5.16 | 5.09 | 5.00 | 4.49 | 4.50 |
| 6 | 1 | 4.74 | 4.66 | 4.56 | 4.28 | 4.25 |
| 6 | 2 | 4.78 | 4.71 | 4.64 | 4.34 | 4.29 |
| 6 | 3 | 4.70 | 4.61 | 4.48 | 4.22 | 4.21 |
| 8 | 1 | 4.49 | 4.39 | 4.36 | 4.13 | 4.08 |
| 8 | 2 | 4.54 | 4.42 | 4.42 | 4.17 | 4.13 |
| 8 | 3 | 4.44 | 4.36 | 4.30 | 4.09 | 4.03 |
| 10 | 1 | 4.30 | 4.25 | 4.21 | 4.05 | 3.98 |
| 10 | 2 | 4.37 | 4.31 | 4.29 | 4.10 | 4.05 |
| 10 | 3 | 4.23 | 4.19 | 4.13 | 4.00 | 3.92 |
| 12 | 1 | 4.19 | 4.13 | 4.09 | 3.98 | 3.92 |
| 12 | 2 | 4.26 | 4.18 | 4.15 | 4.06 | 3.97 |
| 12 | 3 | 4.12 | 4.08 | 4.03 | 3.90 | 3.87 |

D.2.2 The pH of pea protein paste and coconut milk fermentation by different pea protein paste concentration

| Time (h) | Replication | pH (3%) | pH (5%) | pH (7%) | pH (9%) | pH (11%) |
|---|---|---|---|---|---|---|
| 0 | 1 | 6.20 | 6.20 | 6.20 | 6.20 | 6.20 |
| 0 | 2 | 6.20 | 6.20 | 6.20 | 6.20 | 6.20 |
| 0 | 3 | 6.20 | 6.20 | 6.20 | 6.20 | 6.20 |
| 2 | 1 | 5.76 | 5.75 | 5.71 | 5.66 | 5.70 |
| 2 | 2 | 5.79 | 5.77 | 5.75 | 5.68 | 5.67 |
| 2 | 3 | 5.73 | 5.73 | 5.67 | 5.64 | 5.73 |
| 4 | 1 | 5.08 | 5.05 | 5.11 | 5.15 | 5.12 |
| 4 | 2 | 5.13 | 5.11 | 5.16 | 5.18 | 5.17 |
| 4 | 3 | 5.03 | 4.99 | 5.06 | 5.12 | 5.07 |
| 6 | 1 | 4.53 | 4.56 | 4.63 | 4.65 | 4.64 |
| 6 | 2 | 4.57 | 4.61 | 4.66 | 4.71 | 4.60 |
| 6 | 3 | 4.49 | 4.51 | 4.60 | 4.59 | 4.68 |
| 8 | 1 | 4.30 | 4.36 | 4.38 | 4.42 | 4.43 |
| 8 | 2 | 4.35 | 4.39 | 4.44 | 4.46 | 4.48 |
| 8 | 3 | 4.25 | 4.33 | 4.32 | 4.38 | 4.38 |
| 10 | 1 | 4.06 | 4.21 | 4.31 | 4.30 | 4.33 |
| 10 | 2 | 4.46 | 4.24 | 4.25 | 4.34 | 4.38 |
| 10 | 3 | 4.11 | 4.18 | 4.19 | 4.26 | 4.28 |
| 12 | 1 | 4.12 | 4.03 | 4.13 | 4.19 | 4.26 |
| 12 | 2 | 4.05 | 4.15 | 4.21 | 4.24 | 4.19 |
| 12 | 3 | 3.97 | 4.09 | 4.05 | 4.14 | 4.33 |

D.2.3 Viable cell counts (log CFU /mL) of pea protein paste and coconut milk fermentation for 24 hours

| Time (h) | Replication | log CFU /mL |
|---|---|---|
| 0 | 1 | 5.48 |
| 0 | 2 | 5.63 |
| 0 | 3 | 5.33 |
| 2 | 1 | 6.96 |
| 2 | 2 | 7.14 |
| 2 | 3 | 6.78 |
| 4 | 1 | 7.70 |
| 4 | 2 | 7.93 |
| 4 | 3 | 7.47 |
| 6 | 1 | 8.08 |
| 6 | 2 | 8.25 |
| 6 | 3 | 7.91 |
| 8 | 1 | 8.63 |
| 8 | 2 | 8.88 |
| 8 | 3 | 8.38 |
| 10 | 1 | 8.54 |
| 10 | 2 | 8.80 |
| 10 | 3 | 8.28 |
| 12 | 1 | 8.45 |
| 12 | 2 | 8.68 |
| 12 | 3 | 8.22 |
| 14 | 1 | 7.89 |
| 14 | 2 | 7.56 |
| 14 | 3 | 8.23 |
| 16 | 1 | 7.36 |
| 16 | 2 | 7.19 |
| 16 | 3 | 7.54 |
| 18 | 1 | 7.08 |
| 18 | 2 | 7.19 |
| 18 | 3 | 6.94 |
| 20 | 1 | 6.98 |
| 20 | 2 | 7.19 |
| 20 | 3 | 6.77 |
| 22 | 1 | 6.82 |
| 22 | 2 | 7.05 |
| 22 | 3 | 6.63 |
| 24 | 1 | 6.88 |
| 24 | 2 | 6.51 |
| 24 | 3 | 6.74 |

D. 2.4 Viable cell counts (log CFU /mL) for orthogonal test

| Sample | Replication | Cell count /log CFU /mL |
|---|---|---|
| 1 | 1 | 8.78 |
| 1 | 2 | 8.99 |
| 1 | 3 | 8.57 |
| 2 | 1 | 8.54 |
| 2 | 2 | 8.22 |
| 3 | 3 | 8.86 |
| 3 | 1 | 8.43 |
| 3 | 2 | 8.87 |
| 3 | 3 | 7.99 |
| 4 | 1 | 8.65 |
| 4 | 2 | 8.98 |
| 4 | 3 | 8.32 |
| 5 | 1 | 8.18 |
| 5 | 2 | 7.96 |
| 5 | 3 | 8.40 |
| 6 | 1 | 8.52 |
| 6 | 2 | 8.67 |
| 6 | 3 | 8.37 |
| 7 | 1 | 8.51 |
| 7 | 2 | 8.87 |
| 7 | 3 | 8.15 |
| 8 | 1 | 8.41 |
| 8 | 2 | 8.61 |
| 8 | 3 | 8.21 |
| 9 | 1 | 8.00 |
| 9 | 2 | 8.28 |
| 9 | 3 | 7.72 |

D.2.5 Sensory evaluation of semi-trained sensory panel (n=18) of the orthogonal test

Replication 1

| | Sample | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Panelist | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 8 | 2 | 6 | 5 | 5 | 6 | 7 | 5 | 2 |
| 2 | 5 | 5 | 4 | 8 | 5 | 8 | 9 | 8 | 3 |
| 3 | 5 | 7 | 3 | 4 | 5 | 4 | 3 | 7 | 4 |
| 4 | 7 | 5 | 7 | 5 | 1 | 6 | 9 | 5 | 5 |
| 5 | 7 | 3 | 3 | 7 | 4 | 3 | 6 | 4 | 7 |
| 6 | 4 | 8 | 4 | 4 | 4 | 7 | 5 | 4 | 5 |
| Total score | 36 | 30 | 27 | 33 | 24 | 34 | 39 | 33 | 26 |
| Average | 6.0 | 5.0 | 4.5 | 5.5 | 4.0 | 5.7 | 6.5 | 5.5 | 4.3 |

Replication 2

| | Sample | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Panelist | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 7 | 5 | 4 | 8 | 6 | 9 | 8 | 9 | 4 |
| 2 | 9 | 3 | 6 | 5 | 1 | 7 | 7 | 7 | 5 |
| 3 | 7 | 8 | 4 | 7 | 4 | 6 | 6 | 4 | 5 |
| 4 | 6 | 7 | 7 | 5 | 7 | 4 | 7 | 6 | 4 |
| 5 | 6 | 7 | 3 | 6 | 4 | 7 | 4 | 5 | 6 |
| 6 | 7 | 6 | 5 | 4 | 2 | 7 | 3 | 6 | 4 |
| Total score | 42 | 36 | 29 | 35 | 24 | 40 | 35 | 37 | 28 |
| Average | 7.0 | 6.0 | 4.8 | 5.8 | 4.0 | 6.7 | 5.8 | 6.2 | 4.7 |

Replication 3

| | Sample | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Panelist | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 8 | 2 | 3 | 7 | 7 | 8 | 8 | 8 | 3 |
| 2 | 8 | 7 | 6 | 5 | 3 | 6 | 8 | 6 | 4 |
| 3 | 6 | 6 | 4 | 5 | 3 | 5 | 4 | 5 | 4 |
| 4 | 7 | 6 | 7 | 7 | 5 | 5 | 8 | 7 | 7 |
| 5 | 5 | 6 | 4 | 4 | 3 | 5 | 5 | 4 | 6 |
| 6 | 5 | 6 | 4 | 6 | 3 | 8 | 4 | 5 | 3 |
| Total score | 39 | 33 | 28 | 34 | 24 | 37 | 37 | 35 | 27 |
| Average | 6.5 | 5.5 | 4.7 | 5.7 | 4.0 | 6.2 | 6.2 | 5.8 | 4.5 |

D.2.6 Consumer sensory evaluation (n=90) of final fermented pea protein-coconut milk beverage

Replication 1

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 7 | 7 | 4 | 4 | 4 | 5 | 6 | 4 |
| 1 | 2 | 7 | 8 | 5 | 7 | 7 | 6 | 6 | 7 |
| 1 | 3 | 6 | 6 | 7 | 5 | 5 | 4 | 4 | 6 |
| 1 | 4 | 5 | 7 | 3 | 2 | 2 | 5 | 2 | 2 |
| 1 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| 1 | 6 | 7 | 5 | 4 | 4 | 4 | 5 | 4 | 4 |
| 1 | 7 | 8 | 8 | 7 | 6 | 7 | 8 | 8 | 8 |
| 1 | 8 | 5 | 8 | 6 | 6 | 7 | 6 | 6 | 7 |
| 1 | 9 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| 1 | 10 | 8 | 8 | 7 | 6 | 6 | 7 | 7 | 7 |
| 1 | 11 | 7 | 7 | 5 | 5 | 6 | 6 | 5 | 6 |
| 1 | 12 | 5 | 4 | 4 | 5 | 5 | 5 | 6 | 5 |
| 1 | 13 | 7 | 8 | 6 | 4 | 6 | 7 | 7 | 7 |
| 1 | 14 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 1 | 15 | 7 | 7 | 6 | 4 | 5 | 6 | 6 | 6 |
| 1 | 16 | 8 | 7 | 8 | 8 | 8 | 7 | 7 | 8 |
| 1 | 17 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 7 |
| 1 | 18 | 8 | 7 | 8 | 8 | 8 | 7 | 8 | 8 |
| 1 | 19 | 6 | 6 | 6 | 4 | 5 | 5 | 5 | 5 |
| 1 | 20 | 5 | 7 | 2 | 3 | 3 | 3 | 4 | 5 |
| 1 | 21 | 8 | 6 | 7 | 5 | 8 | 8 | 8 | 8 |
| 1 | 22 | 5 | 5 | 6 | 5 | 6 | 6 | 6 | 6 |
| 1 | 23 | 8 | 8 | 6 | 6 | 6 | 6 | 6 | 7 |
| 1 | 24 | 8 | 8 | 5 | 5 | 5 | 9 | 9 | 7 |
| 1 | 25 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 1 | 26 | 8 | 8 | 6 | 5 | 6 | 7 | 6 | 7 |
| 1 | 27 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 8 |
| 1 | 28 | 7 | 7 | 4 | 3 | 3 | 5 | 5 | 4 |
| 1 | 29 | 6 | 5 | 6 | 5 | 6 | 6 | 4 | 6 |
| 1 | 30 | 7 | 8 | 6 | 8 | 8 | 8 | 8 | 8 |
| 1 | Total | 200 | 201 | 171 | 160 | 173 | 183 | 179 | 186 |
| 1 | Average | 6.7 | 6.7 | 5.7 | 5.3 | 5.8 | 6.1 | 6.0 | 6.2 |

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 7 | 7 | 5 | 6 | 6 | 7 | 6 | 6 |
| 6 | 2 | 5 | 7 | 2 | 4 | 1 | 2 | 3 | 2 |
| 6 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 6 | 4 | 5 | 7 | 2 | 2 | 2 | 3 | 2 | 2 |
| 6 | 5 | 5 | 7 | 4 | 5 | 4 | 4 | 5 | 5 |
| 6 | 6 | 7 | 5 | 6 | 4 | 4 | 4 | 5 | 4 |
| 6 | 7 | 8 | 6 | 8 | 7 | 4 | 3 | 3 | 6 |
| 6 | 8 | 5 | 8 | 5 | 5 | 6 | 6 | 6 | 6 |
| 6 | 9 | 5 | 6 | 3 | 5 | 4 | 3 | 4 | 4 |
| 6 | 10 | 7 | 8 | 4 | 6 | 6 | 5 | 5 | 6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 11 | 7 | 5 | 7 | 7 | 7 | 6 | 5 | 7 |
| 6 | 12 | 5 | 6 | 4 | 5 | 6 | 6 | 6 | 6 |
| 6 | 13 | 7 | 8 | 4 | 7 | 7 | 7 | 7 | 6 |
| 6 | 14 | 6 | 6 | 3 | 4 | 3 | 6 | 6 | 5 |
| 6 | 15 | 7 | 6 | 4 | 5 | 6 | 4 | 6 | 6 |
| 6 | 16 | 7 | 6 | 5 | 5 | 6 | 5 | 5 | 6 |
| 6 | 17 | 7 | 5 | 7 | 6 | 6 | 7 | 7 | 6 |
| 6 | 18 | 8 | 8 | 6 | 5 | 6 | 7 | 6 | 6 |
| 6 | 19 | 6 | 5 | 3 | 2 | 4 | 4 | 4 | 4 |
| 6 | 20 | 5 | 8 | 2 | 3 | 5 | 2 | 3 | 3 |
| 6 | 21 | 8 | 8 | 3 | 4 | 5 | 7 | 6 | 7 |
| 6 | 22 | 5 | 5 | 6 | 5 | 7 | 7 | 6 | 6.5 |
| 6 | 23 | 8 | 8 | 5 | 5 | 5 | 6 | 5 | 5 |
| 6 | 24 | 8 | 9 | 7 | 9 | 9 | 9 | 9 | 9 |
| 6 | 25 | 4 | 6 | 4 | 5 | 4 | 4 | 5 | 4 |
| 6 | 26 | 6 | 6 | 6 | 5 | 6 | 7 | 6 | 7 |
| 6 | 27 | 7 | 8 | 6 | 7 | 7 | 8 | 8 | 8 |
| 6 | 28 | 7 | 5 | 2 | 3 | 2 | 5 | 5 | 2 |
| 6 | 29 | 6 | 5 | 6 | 6 | 7 | 7 | 6 | 6 |
| 6 | 30 | 7 | 8 | 7 | 8 | 8 | 8 | 8 | 8 |
| 6 | Total | 191 | 198 | 142 | 156 | 159 | 165 | 164 | 164.5 |
| 6 | Average | 6.4 | 6.6 | 4.7 | 5.2 | 5.3 | 5.5 | 5.5 | 5.5 |

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 1 | 7 | 6 | 5 | 6 | 6 | 5 | 6 | 6 |
| 7 | 2 | 7 | 7 | 4 | 5 | 5 | 5 | 5 | 6 |
| 7 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 |
| 7 | 4 | 5 | 7 | 4 | 4 | 2 | 3 | 2 | 2 |
| 7 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 |
| 7 | 6 | 7 | 7 | 7 | 7 | 7 | 4 | 6 | 7 |
| 7 | 7 | 8 | 5 | 6 | 5 | 4 | 3 | 3 | 4 |
| 7 | 8 | 5 | 8 | 4 | 5 | 6 | 5 | 5 | 6 |
| 7 | 9 | 6 | 5 | 5 | 6 | 5 | 5 | 5 | 5 |
| 7 | 10 | 7 | 8 | 6 | 6 | 7 | 7 | 8 | 7 |
| 7 | 11 | 6 | 5 | 6 | 7 | 6 | 6 | 5 | 6 |
| 7 | 12 | 5 | 5 | 5 | 6 | 7 | 6 | 5 | 7 |
| 7 | 13 | 8 | 8 | 7 | 6 | 6 | 4 | 4 | 6 |
| 7 | 14 | 6 | 6 | 3 | 3 | 2 | 1 | 7 | 5 |
| 7 | 15 | 7 | 6 | 6 | 5 | 4 | 6 | 6 | 6 |
| 7 | 16 | 7 | 6 | 7 | 6 | 8 | 7 | 5 | 6 |
| 7 | 17 | 7 | 6 | 6 | 6 | 7 | 7 | 6 | 6 |
| 7 | 18 | 8 | 7 | 8 | 7 | 7 | 7 | 6 | 7 |
| 7 | 19 | 6 | 7 | 4 | 4 | 5 | 5 | 5 | 5 |
| 7 | 20 | 5 | 8 | 3 | 7 | 6 | 6 | 6 | 6 |
| 7 | 21 | 6 | 5 | 4 | 5 | 6 | 6 | 6 | 5 |
| 7 | 22 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 5 |
| 7 | 23 | 8 | 7 | 4 | 6 | 5 | 2 | 4 | 3 |
| 7 | 24 | 8 | 8 | 6 | 6 | 6 | 8 | 8 | 8 |
| 7 | 25 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 7 | 26 | 8 | 8 | 3 | 5 | 3 | 3 | 3 | 4 |
| 7 | 27 | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| 7 | 28 | 7 | 7 | 4 | 3 | 3 | 5 | 5 | 4 |
| 7 | 29 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| 7 | 30 | 7 | 8 | 6 | 8 | 8 | 9 | 8 | 8 |
| 7 | Total | 192 | 192 | 153 | 165 | 160 | 154 | 159 | 164 |
| 7 | Average | 6.4 | 6.4 | 5.1 | 5.5 | 5.3 | 5.1 | 5.3 | 5.5 |

Replication 2

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 7 | 7 | 4 | 4 | 4 | 5 | 6 | 4 |
| 1 | 2 | 7 | 8 | 5 | 7 | 7 | 6 | 6 | 7 |
| 1 | 3 | 6 | 6 | 7 | 5 | 5 | 4 | 4 | 6 |
| 1 | 4 | 5 | 7 | 4 | 2 | 2 | 5 | 2 | 2 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| 1 | 6 | 7 | 5 | 4 | 4 | 4 | 5 | 4 | 4 |
| 1 | 7 | 8 | 8 | 7 | 8 | 7 | 8 | 7 | 8 |
| 1 | 8 | 6 | 8 | 6 | 6 | 5 | 6 | 6 | 7 |
| 1 | 9 | 5 | 6 | 5 | 5 | 5 | 4 | 4 | 5 |
| 1 | 10 | 8 | 8 | 7 | 6 | 6 | 7 | 7 | 7 |
| 1 | 11 | 7 | 7 | 5 | 5 | 6 | 6 | 5 | 6 |
| 1 | 12 | 6 | 5 | 6 | 7 | 5 | 5 | 6 | 6 |
| 1 | 13 | 7 | 8 | 6 | 4 | 6 | 7 | 6 | 7 |
| 1 | 14 | 6 | 6 | 6 | 6 | 6 | 5 | 6 | 6 |
| 1 | 15 | 8 | 7 | 6 | 4 | 5 | 5 | 6 | 6 |
| 1 | 16 | 8 | 7 | 8 | 8 | 6 | 6 | 7 | 8 |
| 1 | 17 | 7 | 6 | 7 | 7 | 7 | 6 | 7 | 7 |
| 1 | 18 | 8 | 7 | 6 | 8 | 6 | 6 | 7 | 8 |
| 1 | 19 | 6 | 6 | 6 | 4 | 5 | 4 | 5 | 5 |
| 1 | 20 | 6 | 7 | 4 | 5 | 3 | 3 | 4 | 6 |
| 1 | 21 | 8 | 7 | 7 | 5 | 8 | 8 | 8 | 8 |
| 1 | 22 | 6 | 5 | 6 | 5 | 6 | 6 | 6 | 6 |
| 1 | 23 | 8 | 7 | 6 | 6 | 6 | 6 | 6 | 7 |
| 1 | 24 | 7 | 8 | 7 | 5 | 5 | 9 | 9 | 7 |
| 1 | 25 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 1 | 26 | 8 | 8 | 6 | 5 | 6 | 7 | 6 | 7 |
| 1 | 27 | 7 | 8 | 7 | 7 | 7 | 7 | 7 | 8 |
| 1 | 28 | 7 | 7 | 5 | 3 | 3 | 5 | 5 | 5 |
| 1 | 29 | 6 | 5 | 6 | 5 | 6 | 6 | 4 | 6 |
| 1 | 30 | 7 | 8 | 6 | 8 | 8 | 8 | 8 | 8 |
| 1 | Total | 203 | 203 | 177 | 166 | 167 | 177 | 176 | 189 |
| 1 | Average | 6.8 | 6.8 | 5.9 | 5.5 | 5.6 | 5.9 | 5.9 | 6.3 |

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 7 | 7 | 5 | 6 | 6 | 7 | 6 | 6 |
| 6 | 2 | 5 | 7 | 2 | 4 | 1 | 2 | 3 | 2 |
| 6 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 6 | 4 | 5 | 7 | 2 | 2 | 2 | 3 | 2 | 2 |
| 6 | 5 | 5 | 7 | 4 | 5 | 4 | 4 | 5 | 5 |
| 6 | 6 | 7 | 5 | 6 | 4 | 4 | 4 | 5 | 4 |
| 6 | 7 | 8 | 6 | 8 | 7 | 4 | 3 | 3 | 6 |
| 6 | 8 | 5 | 8 | 5 | 5 | 6 | 6 | 6 | 6 |
| 6 | 9 | 5 | 6 | 3 | 5 | 4 | 3 | 4 | 3 |
| 6 | 10 | 7 | 8 | 4 | 6 | 6 | 5 | 5 | 6 |
| 6 | 11 | 7 | 5 | 7 | 7 | 7 | 6 | 5 | 7 |
| 6 | 12 | 5 | 6 | 4 | 5 | 6 | 6 | 6 | 6 |
| 6 | 13 | 7 | 8 | 5 | 7 | 7 | 7 | 7 | 6 |
| 6 | 14 | 6 | 6 | 3 | 4 | 3 | 6 | 6 | 5 |
| 6 | 15 | 7 | 6 | 4 | 5 | 6 | 4 | 6 | 6 |
| 6 | 16 | 7 | 6 | 5 | 5 | 6 | 5 | 5 | 6 |
| 6 | 17 | 7 | 5 | 7 | 6 | 6 | 7 | 5 | 6 |
| 6 | 18 | 8 | 8 | 6 | 5 | 6 | 7 | 6 | 6 |
| 6 | 19 | 6 | 5 | 3 | 2 | 4 | 4 | 4 | 4 |
| 6 | 20 | 5 | 8 | 2 | 3 | 5 | 2 | 3 | 3 |
| 6 | 21 | 8 | 8 | 3 | 4 | 5 | 7 | 6 | 7 |
| 6 | 22 | 5 | 5 | 6 | 5 | 7 | 7 | 6 | 6.0 |
| 6 | 23 | 8 | 8 | 5 | 5 | 5 | 6 | 5 | 5 |
| 6 | 24 | 8 | 9 | 7 | 9 | 9 | 9 | 7 | 9 |
| 6 | 25 | 4 | 6 | 4 | 5 | 4 | 4 | 5 | 4 |
| 6 | 26 | 6 | 6 | 6 | 5 | 6 | 7 | 6 | 7 |
| 6 | 27 | 7 | 8 | 6 | 7 | 7 | 8 | 6 | 7 |
| 6 | 28 | 7 | 5 | 2 | 3 | 2 | 5 | 5 | 2 |
| 6 | 29 | 6 | 5 | 6 | 6 | 7 | 7 | 6 | 6 |
| 6 | 30 | 7 | 8 | 7 | 8 | 8 | 8 | 8 | 8 |
| 6 | Total | 191 | 198 | 143 | 156 | 159 | 165 | 158 | 162 |
| 6 | Average | 6.4 | 6.6 | 4.8 | 5.2 | 5.3 | 5.5 | 5.3 | 5.4 |

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 1 | 7 | 6 | 5 | 6 | 6 | 5 | 6 | 6 |
| 7 | 2 | 7 | 7 | 4 | 5 | 5 | 5 | 5 | 6 |
| 7 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 |
| 7 | 4 | 5 | 7 | 4 | 4 | 2 | 3 | 2 | 2 |
| 7 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 |
| 7 | 6 | 7 | 7 | 7 | 7 | 7 | 4 | 6 | 7 |
| 7 | 7 | 8 | 5 | 6 | 5 | 4 | 3 | 3 | 5 |
| 7 | 8 | 5 | 8 | 4 | 5 | 6 | 5 | 5 | 6 |
| 7 | 9 | 6 | 5 | 5 | 6 | 5 | 5 | 5 | 5 |
| 7 | 10 | 7 | 8 | 6 | 6 | 7 | 7 | 8 | 7 |
| 7 | 11 | 6 | 5 | 6 | 7 | 6 | 6 | 5 | 8 |
| 7 | 12 | 5 | 5 | 5 | 6 | 7 | 6 | 5 | 7 |
| 7 | 13 | 8 | 8 | 7 | 6 | 6 | 4 | 4 | 6 |
| 7 | 14 | 6 | 6 | 3 | 4 | 2 | 1 | 7 | 5 |
| 7 | 15 | 7 | 6 | 6 | 5 | 4 | 6 | 6 | 6 |
| 7 | 16 | 7 | 6 | 7 | 6 | 8 | 7 | 5 | 6 |
| 7 | 17 | 7 | 6 | 6 | 6 | 7 | 7 | 6 | 6 |
| 7 | 18 | 8 | 7 | 8 | 7 | 7 | 7 | 6 | 7 |
| 7 | 19 | 6 | 7 | 4 | 5 | 5 | 5 | 5 | 5 |
| 7 | 20 | 5 | 8 | 3 | 7 | 6 | 6 | 6 | 6 |
| 7 | 21 | 6 | 5 | 4 | 5 | 6 | 6 | 6 | 5 |
| 7 | 22 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 5 |
| 7 | 23 | 8 | 7 | 4 | 6 | 5 | 2 | 4 | 5 |
| 7 | 24 | 8 | 8 | 6 | 6 | 6 | 8 | 8 | 8 |
| 7 | 25 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 7 | 26 | 8 | 8 | 3 | 5 | 3 | 3 | 3 | 4 |
| 7 | 27 | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| 7 | 28 | 7 | 7 | 4 | 4 | 3 | 5 | 5 | 4 |
| 7 | 29 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| 7 | 30 | 7 | 8 | 6 | 8 | 8 | 9 | 8 | 8 |
| 7 | Total | 192 | 192 | 153 | 168 | 160 | 154 | 159 | 169 |
| 7 | Average | 6.4 | 6.4 | 5.1 | 5.6 | 5.3 | 5.1 | 5.3 | 5.6 |

Replication 3

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 7 | 7 | 4 | 4 | 4 | 5 | 6 | 4 |
| 1 | 2 | 7 | 8 | 5 | 7 | 7 | 6 | 6 | 7 |
| 1 | 3 | 6 | 6 | 7 | 5 | 5 | 4 | 4 | 6 |
| 1 | 4 | 5 | 7 | 3 | 2 | 2 | 5 | 2 | 2 |
| 1 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| 1 | 6 | 7 | 5 | 4 | 4 | 4 | 5 | 4 | 4 |
| 1 | 7 | 8 | 8 | 5 | 6 | 7 | 8 | 8 | 7 |
| 1 | 8 | 5 | 8 | 6 | 3 | 7 | 6 | 6 | 7 |
| 1 | 9 | 5 | 5 | 5 | 5 | 7 | 6 | 5 | 5 |
| 1 | 10 | 8 | 8 | 5 | 6 | 6 | 7 | 7 | 7 |
| 1 | 11 | 6 | 7 | 5 | 5 | 6 | 6 | 5 | 6 |
| 1 | 12 | 5 | 4 | 4 | 5 | 5 | 5 | 6 | 5 |
| 1 | 13 | 7 | 7 | 6 | 4 | 6 | 7 | 7 | 7 |
| 1 | 14 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 1 | 15 | 7 | 7 | 6 | 4 | 5 | 6 | 6 | 6 |
| 1 | 16 | 7 | 7 | 8 | 8 | 8 | 7 | 7 | 7 |
| 1 | 17 | 7 | 6 | 7 | 7 | 7 | 7 | 7 | 7 |
| 1 | 18 | 8 | 7 | 8 | 6 | 8 | 7 | 8 | 8 |
| 1 | 19 | 6 | 6 | 6 | 4 | 5 | 5 | 5 | 5 |
| 1 | 20 | 5 | 7 | 2 | 3 | 5 | 5 | 5 | 5 |
| 1 | 21 | 8 | 6 | 5 | 5 | 8 | 8 | 8 | 8 |
| 1 | 22 | 5 | 5 | 6 | 5 | 6 | 6 | 6 | 6 |
| 1 | 23 | 8 | 7 | 6 | 6 | 6 | 6 | 6 | 7 |
| 1 | 24 | 8 | 8 | 5 | 5 | 5 | 9 | 9 | 7 |
| 1 | 25 | 5 | 6 | 6 | 6 | 6 | 6 | 6 | 5 |
| 1 | 26 | 8 | 8 | 6 | 5 | 6 | 7 | 7 | 7 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 27 | 8 | 8 | 7 | 5 | 7 | 7 | 7 | 8 |
| 1 | 28 | 7 | 7 | 4 | 3 | 5 | 7 | 5 | 4 |
| 1 | 29 | 6 | 5 | 6 | 5 | 6 | 6 | 4 | 6 |
| 1 | 30 | 7 | 8 | 6 | 8 | 8 | 8 | 8 | 8 |
| 1 | Total | 197 | 199 | 165 | 153 | 179 | 189 | 182 | 183 |
| 1 | Average | 6.6 | 6.6 | 5.5 | 5.1 | 6.0 | 6.3 | 6.1 | 6.1 |

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 7 | 7 | 5 | 6 | 6 | 7 | 6 | 6 |
| 6 | 2 | 5 | 7 | 2 | 4 | 1 | 2 | 3 | 2 |
| 6 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 6 | 4 | 5 | 7 | 2 | 2 | 2 | 3 | 2 | 2 |
| 6 | 5 | 5 | 7 | 4 | 5 | 4 | 4 | 5 | 5 |
| 6 | 6 | 7 | 5 | 6 | 4 | 4 | 4 | 5 | 4 |
| 6 | 7 | 8 | 6 | 8 | 7 | 4 | 3 | 3 | 6 |
| 6 | 8 | 5 | 8 | 5 | 5 | 6 | 6 | 6 | 6 |
| 6 | 9 | 5 | 6 | 3 | 5 | 4 | 3 | 6 | 4 |
| 6 | 10 | 7 | 8 | 4 | 6 | 6 | 5 | 5 | 6 |
| 6 | 11 | 7 | 5 | 7 | 7 | 7 | 6 | 5 | 8 |
| 6 | 12 | 5 | 6 | 4 | 5 | 6 | 6 | 6 | 6 |
| 6 | 13 | 7 | 8 | 4 | 7 | 7 | 7 | 7 | 6 |
| 6 | 14 | 6 | 6 | 3 | 4 | 3 | 6 | 6 | 5 |
| 6 | 15 | 7 | 6 | 4 | 5 | 6 | 4 | 6 | 6 |
| 6 | 16 | 7 | 6 | 4 | 5 | 6 | 5 | 7 | 7 |
| 6 | 17 | 7 | 5 | 7 | 6 | 6 | 7 | 7 | 6 |
| 6 | 18 | 8 | 8 | 6 | 5 | 6 | 7 | 6 | 6 |
| 6 | 19 | 6 | 5 | 3 | 2 | 4 | 4 | 4 | 4 |
| 6 | 20 | 5 | 8 | 3 | 3 | 5 | 2 | 5 | 3 |
| 6 | 21 | 8 | 8 | 3 | 4 | 5 | 7 | 6 | 7 |
| 6 | 22 | 5 | 5 | 6 | 5 | 7 | 7 | 6 | 7.0 |
| 6 | 23 | 8 | 8 | 5 | 5 | 5 | 6 | 5 | 5 |
| 6 | 24 | 8 | 9 | 6 | 9 | 9 | 9 | 9 | 9 |
| 6 | 25 | 4 | 6 | 4 | 5 | 4 | 4 | 5 | 4 |
| 6 | 26 | 6 | 6 | 5 | 5 | 6 | 7 | 6 | 7 |
| 6 | 27 | 7 | 8 | 6 | 7 | 7 | 8 | 8 | 8 |
| 6 | 28 | 7 | 5 | 3 | 3 | 2 | 5 | 5 | 2 |
| 6 | 29 | 6 | 5 | 6 | 6 | 7 | 7 | 6 | 6 |
| 6 | 30 | 7 | 8 | 7 | 8 | 8 | 8 | 8 | 8 |
| 6 | Total | 191 | 198 | 141 | 156 | 159 | 165 | 170 | 167 |
| 6 | Average | 6.4 | 6.6 | 4.7 | 5.2 | 5.3 | 5.5 | 5.7 | 5.6 |

| Sample | Panelists | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 1 | 7 | 6 | 5 | 6 | 6 | 5 | 6 | 6 |
| 7 | 2 | 7 | 7 | 4 | 5 | 5 | 5 | 5 | 6 |
| 7 | 3 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 |
| 7 | 4 | 5 | 7 | 4 | 4 | 2 | 3 | 2 | 2 |
| 7 | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 |
| 7 | 6 | 7 | 7 | 7 | 7 | 7 | 4 | 6 | 6 |
| 7 | 7 | 8 | 5 | 6 | 5 | 4 | 3 | 3 | 4 |
| 7 | 8 | 5 | 8 | 4 | 5 | 6 | 5 | 5 | 6 |
| 7 | 9 | 6 | 5 | 5 | 6 | 5 | 5 | 5 | 5 |
| 7 | 10 | 7 | 8 | 6 | 6 | 7 | 7 | 8 | 5 |
| 7 | 11 | 6 | 5 | 6 | 7 | 6 | 6 | 5 | 6 |
| 7 | 12 | 5 | 5 | 5 | 6 | 7 | 6 | 5 | 7 |
| 7 | 13 | 8 | 8 | 7 | 6 | 6 | 4 | 4 | 6 |
| 7 | 14 | 6 | 6 | 3 | 3 | 2 | 1 | 7 | 5 |
| 7 | 15 | 7 | 6 | 6 | 5 | 4 | 6 | 6 | 6 |
| 7 | 16 | 7 | 6 | 7 | 6 | 8 | 7 | 5 | 6 |
| 7 | 17 | 7 | 6 | 6 | 5 | 7 | 7 | 6 | 6 |
| 7 | 18 | 8 | 7 | 8 | 6 | 7 | 7 | 6 | 7 |
| 7 | 19 | 6 | 7 | 4 | 4 | 5 | 5 | 5 | 5 |
| 7 | 20 | 5 | 8 | 3 | 7 | 6 | 6 | 6 | 6 |
| 7 | 21 | 6 | 5 | 4 | 5 | 6 | 6 | 6 | 5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 22 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 5 |
| 7 | 23 | 8 | 7 | 4 | 6 | 5 | 2 | 4 | 3 |
| 7 | 24 | 8 | 8 | 6 | 6 | 6 | 8 | 8 | 6 |
| 7 | 25 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 7 | 26 | 8 | 8 | 3 | 5 | 3 | 3 | 3 | 4 |
| 7 | 27 | 6 | 5 | 6 | 5 | 6 | 6 | 6 | 6 |
| 7 | 28 | 7 | 7 | 4 | 3 | 3 | 5 | 5 | 4 |
| 7 | 29 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 |
| 7 | 30 | 7 | 8 | 6 | 8 | 8 | 9 | 8 | 8 |
| 7 | Total | 192 | 192 | 153 | 162 | 160 | 154 | 159 | 159 |
| 7 | Average | 6.4 | 6.4 | 5.1 | 5.4 | 5.3 | 5.1 | 5.3 | 5.3 |

D.2.7 The pH and titratable acid of fermented pea protein-coconut milk beverage during the fermentation

| Time (h) | Replication | pH | T.A. (mL) | T.A. (%) |
|---|---|---|---|---|
| 0 | 1 | 6.30 | 0.55 | 0.10 |
| 0 | 2 | 6.09 | 0.50 | 0.09 |
| 0 | 3 | 6.07 | 0.50 | 0.09 |
| 2 | 1 | 6.05 | 0.65 | 0.12 |
| 2 | 2 | 5.93 | 0.60 | 0.11 |
| 2 | 3 | 5.98 | 0.70 | 0.13 |
| 4 | 1 | 5.03 | 1.20 | 0.22 |
| 4 | 2 | 5.21 | 1.40 | 0.25 |
| 4 | 3 | 5.17 | 1.50 | 0.27 |
| 6 | 1 | 4.50 | 1.70 | 0.31 |
| 6 | 2 | 4.59 | 2.00 | 0.36 |
| 6 | 3 | 4.53 | 1.90 | 0.34 |
| 8 | 1 | 4.28 | 2.90 | 0.52 |
| 8 | 2 | 4.31 | 2.70 | 0.49 |
| 8 | 3 | 4.28 | 3.00 | 0.54 |

D.2.8 VCCs (log CFU /mL) of fermented pea protein-coconut milk beverage during the fermentation

| Time (h) | Replication | Log CFU /mL |
|---|---|---|
| 0 | 1 | 5.54 |
| 0 | 2 | 5.44 |
| 0 | 3 | 5.64 |
| 2 | 1 | 6.99 |
| 2 | 2 | 6.71 |
| 2 | 3 | 7.27 |
| 4 | 1 | 7.85 |
| 4 | 2 | 7.55 |
| 4 | 3 | 8.15 |
| 6 | 1 | 8.18 |
| 6 | 2 | 8.52 |
| 6 | 3 | 7.84 |
| 8 | 1 | 8.61 |
| 8 | 2 | 8.96 |
| 8 | 3 | 8.26 |

D.2.9 Colour of fermented pea protein-coconut milk beverage during the fermentation

| Time (h) | Replication | L* | a* | b* |
|---|---|---|---|---|
| 0 | 1 | 73.23 | 0.04 | 3.01 |
| 0 | 2 | 73.71 | 0.03 | 3.03 |
| 0 | 3 | 73.25 | 0.03 | 2.94 |
| 2 | 1 | 73.58 | 0.03 | 3.15 |
| 2 | 2 | 73.75 | 0.02 | 3.98 |
| 2 | 3 | 73.46 | 0.03 | 3.57 |
| 4 | 1 | 74.65 | 0.02 | 3.96 |
| 4 | 2 | 73.93 | 0.01 | 4.68 |
| 4 | 3 | 74.06 | 0.01 | 3.77 |
| 6 | 1 | 74.34 | -0.01 | 4.59 |
| 6 | 2 | 74.27 | -0.02 | 5.08 |
| 6 | 3 | 74.19 | -0.02 | 4.96 |
| 8 | 1 | 74.48 | -0.03 | 5.06 |
| 8 | 2 | 74.73 | -0.02 | 4.61 |
| 8 | 3 | 74.22 | -0.02 | 5.2 |

D.2.10 Sugars and organic acids in fermented pea protein-coconut milk beverage during fermentation

Sugars

| Time (h) | Replication | Peak area | Sucrose concentration (%) (w /v) |
|---|---|---|---|
| 0 | 1 | 250250 | 2.27 |
| 0 | 2 | 239824 | 2.17 |
| 0 | 3 | 240037 | 2.17 |
| 2 | 1 | 231999 | 2.09 |
| 2 | 2 | 231915 | 2.09 |
| 2 | 3 | 221957 | 1.99 |
| 4 | 1 | 234406 | 2.11 |
| 4 | 2 | 224236 | 2.01 |
| 4 | 3 | 224321 | 2.01 |
| 6 | 1 | 223234 | 2.00 |
| 6 | 2 | 213204 | 1.90 |
| 6 | 3 | 213219 | 1.90 |
| 8 | 1 | 211535 | 1.88 |
| 8 | 2 | 204918 | 1.82 |
| 8 | 3 | 203226 | 1.80 |

| Time (h) | Replication | Peak area | Fructose concentration (%) (w /v) |
|---|---|---|---|
| 0 | 1 | 137585 | 0.14 |
| 0 | 2 | 147936 | 0.15 |
| 0 | 3 | 137764 | 0.14 |
| 2 | 1 | 166992 | 0.17 |
| 2 | 2 | 166131 | 0.16 |
| 2 | 3 | 186567 | 0.18 |
| 4 | 1 | 215193 | 0.21 |
| 4 | 2 | 236206 | 0.23 |
| 4 | 3 | 205697 | 0.20 |
| 6 | 1 | 255144 | 0.25 |
| 6 | 2 | 264005 | 0.26 |
| 6 | 3 | 224577 | 0.22 |
| 8 | 1 | 293453 | 0.29 |
| 8 | 2 | 253956 | 0.25 |
| 8 | 3 | 261377 | 0.26 |

Organic acids

| Time (h) | Replication | Peak area | Lactic acid concentration (%) (w /v) |
|---|---|---|---|
| 0 | 1 | 25120 | 0.23 |
| 0 | 2 | 32916 | 0.24 |
| 0 | 3 | 29018 | 0.24 |
| 2 | 1 | 121602 | 0.36 |
| 2 | 2 | 110391 | 0.34 |
| 2 | 3 | 110997 | 0.34 |
| 4 | 1 | 344806 | 0.63 |
| 4 | 2 | 434095 | 0.75 |
| 4 | 3 | 374451 | 0.67 |
| 6 | 1 | 624723 | 0.98 |
| 6 | 2 | 601136 | 0.95 |
| 6 | 3 | 567930 | 0.91 |
| 8 | 1 | 753267 | 1.14 |
| 8 | 2 | 896269 | 1.32 |
| 8 | 3 | 824768 | 1.23 |

| Time (h) | Replication | Peak area | Acetic acid concentration (%) (w /v) |
|---|---|---|---|
| 0 | 1 | 1302465 | 1.86 |
| 0 | 2 | 1024368 | 1.56 |
| 0 | 3 | 1213417 | 1.77 |
| 2 | 1 | 1371017 | 1.94 |
| 2 | 2 | 1224689 | 1.78 |
| 2 | 3 | 1347853 | 1.91 |
| 4 | 1 | 1971421 | 2.61 |
| 4 | 2 | 2177164 | 2.84 |
| 4 | 3 | 2024293 | 2.67 |
| 6 | 1 | 3052353 | 3.81 |
| 6 | 2 | 2785200 | 3.51 |
| 6 | 3 | 2868777 | 3.60 |
| 8 | 1 | 3266394 | 4.05 |
| 8 | 2 | 3365445 | 4.16 |
| 8 | 3 | 3065920 | 3.82 |

## D.2.11 Protein content in fermented pea protein-coconut milk beverage during fermentation

| Time (h) | Replication | Nitrogen % | Protein % |
|---|---|---|---|
| 0 | 1 | 0.36 | 2.25 |
| 0 | 2 | 0.35 | 2.19 |
| 0 | 3 | 0.36 | 2.22 |
| 2 | 1 | 0.35 | 2.19 |
| 2 | 2 | 0.36 | 2.25 |
| 2 | 3 | 0.37 | 2.31 |
| 4 | 1 | 0.37 | 2.31 |
| 4 | 2 | 0.36 | 2.25 |
| 4 | 3 | 0.36 | 2.38 |
| 6 | 1 | 0.37 | 2.31 |
| 6 | 2 | 0.37 | 2.31 |
| 6 | 3 | 0.38 | 2.38 |
| 8 | 1 | 0.37 | 2.31 |
| 8 | 2 | 0.39 | 2.44 |
| 8 | 3 | 0.38 | 2.38 |

## D.3 Raw data phase 3: Stability of fermented pea protein-coconut milk beverage during storage at 4 °C for 21 days

D.3.1 pH and titratable acid changes of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

| Store days | Replication | pH | T.A. (mL) | T.A. (%) |
|---|---|---|---|---|
| 1 | 1 | 4.40 | 2.90 | 0.52 |
| | 2 | 4.46 | 3.00 | 0.54 |
| | 3 | 4.43 | 2.95 | 0.53 |
| 7 | 1 | 4.41 | 3.00 | 0.54 |
| | 2 | 4.37 | 3.10 | 0.56 |
| | 3 | 4.39 | 3.05 | 0.55 |
| 14 | 1 | 4.40 | 3.05 | 0.55 |
| | 2 | 4.32 | 3.15 | 0.57 |
| | 3 | 4.36 | 3.10 | 0.56 |
| 21 | 1 | 4.36 | 3.05 | 0.55 |
| | 2 | 4.40 | 3.08 | 0.55 |
| | 3 | 4.38 | 3.02 | 0.54 |

D.3.2 Bacterial content of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

| Store days | Replication | CFU /mL | Log CFU /mL |
|---|---|---|---|
| 1 | 1 | 4.3E+08 | 8.63 |
| | 2 | 5.0E+08 | 8.70 |
| | 3 | 4.6E+08 | 8.66 |
| 7 | 1 | 5.0E+08 | 8.70 |
| | 2 | 5.4E+08 | 8.73 |
| | 3 | 4.9E+08 | 8.69 |
| 14 | 1 | 5.0E+08 | 8.70 |
| | 2 | 5.3E+08 | 8.72 |
| | 3 | 5.6E+08 | 8.75 |
| 21 | 1 | 5.0E+08 | 8.70 |
| | 2 | 4.8E+08 | 8.68 |
| | 3 | 5.1E+08 | 8.71 |

D.3.3 Colour of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

| Store days | Replication | L* | a* | b* |
|---|---|---|---|---|
| 1 | 1 | 74.48 | -0.03 | +5.06 |
| | 2 | 74.73 | -0.02 | +4.61 |
| | 3 | 74.22 | -0.02 | +5.20 |
| 7 | 1 | 75.39 | -0.01 | +5.67 |
| | 2 | 75.98 | -0.01 | +5.00 |
| | 3 | 74.76 | -0.03 | +4.84 |
| 14 | 1 | 75.94 | +0.32 | +4.36 |
| | 2 | 75.72 | +0.31 | +4.36 |
| | 3 | 75.61 | +0.31 | +4.31 |
| 21 | 1 | 70.86 | +0.30 | +4.39 |
| | 2 | 73.48 | +0.44 | +3.94 |
| | 3 | 72.88 | +0.39 | +4.16 |

D.3.4 Sugars and organic acid change of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

Sugars

| Store days | Replication | Peak area | Sucrose concentration (%) (w /v) |
|---|---|---|---|
| 1 | 1 | 330159 | 3.07 |
| | 2 | 325356 | 3.02 |
| | 3 | 327758 | 3.05 |
| 7 | 1 | 307955 | 2.85 |
| | 2 | 298087 | 2.75 |
| | 3 | 303021 | 2.80 |
| 14 | 1 | 266207 | 2.43 |
| | 2 | 264667 | 2.41 |
| | 3 | 265437 | 2.42 |
| 21 | 1 | 191145 | 1.68 |
| | 2 | 192065 | 1.69 |
| | 3 | 191605 | 1.68 |

| Store days | Replication | Peak area | Fructose concentration (%) (w /v) |
|---|---|---|---|
| 1 | 1 | 185789 | 0.18 |
| | 2 | 166537 | 0.16 |
| | 3 | 216163 | 0.21 |
| 7 | 1 | 197242 | 0.20 |
| | 2 | 218658 | 0.22 |
| | 3 | 257950 | 0.26 |
| 14 | 1 | 247238 | 0.25 |
| | 2 | 275242 | 0.27 |
| | 3 | 226240 | 0.22 |
| 21 | 1 | 237909 | 0.24 |
| | 2 | 293654 | 0.29 |
| | 3 | 275782 | 0.27 |

Organic acids

| Store days | Replication | Peak area | Lactic acid concentration (%) (w /v) |
|---|---|---|---|
| 1 | 1 | 992772 | 1.44 |
| | 2 | 934784 | 1.37 |
| | 3 | 963778 | 1.41 |
| 7 | 1 | 928068 | 1.36 |
| | 2 | 929661 | 1.37 |
| | 3 | 928865 | 1.36 |
| 14 | 1 | 932852 | 1.37 |
| | 2 | 898516 | 1.33 |
| | 3 | 915684 | 1.35 |
| 21 | 1 | 923813 | 1.36 |
| | 2 | 867798 | 1.29 |
| | 3 | 895806 | 1.32 |

| Store days | Replication | Peak area | Acetic acid concentration (%) (w /v) |
|---|---|---|---|
| 1 | 1 | 1998828 | 2.64 |
| | 2 | 1952953 | 2.59 |
| | 3 | 1975891 | 2.61 |
| 7 | 1 | 1938087 | 2.57 |
| | 2 | 1848903 | 2.47 |
| | 3 | 1893495 | 2.52 |
| 14 | 1 | 1859720 | 2.48 |
| | 2 | 1825137 | 2.44 |
| | 3 | 1892429 | 2.52 |
| 21 | 1 | 1536030 | 2.12 |
| | 2 | 1523878 | 2.11 |
| | 3 | 1529954 | 2.12 |

D.3.5 Protein content of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

| Store days | Replication | Nitrogen % | Protein % |
|---|---|---|---|
| 1 | 1 | 0.33 | 2.06 |
| | 2 | 0.32 | 2.00 |
| | 3 | 0.31 | 1.94 |
| 7 | 1 | 0.33 | 2.06 |
| | 2 | 0.34 | 2.13 |
| | 3 | 0.35 | 2.19 |
| 14 | 1 | 0.35 | 2.19 |
| | 2 | 0.35 | 2.19 |
| | 3 | 0.35 | 2.19 |
| 21 | 1 | 0.35 | 2.19 |
| | 2 | 0.34 | 2.13 |
| | 3 | 0.33 | 2.06 |

D.3.6 Sensory evaluation of semi-trained sensory panel (n=15) of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

Replication 1

| Store days | Panellist | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 7 | 6 | 6 | 7 | 8 | 7 | 6 | 8 |
| 1 | 2 | 5 | 6 | 4 | 5 | 5 | 4 | 6 | 6 |
| 1 | 3 | 6 | 6 | 4 | 5 | 4 | 6 | 7 | 6 |
| 1 | 4 | 8 | 8 | 7 | 8 | 8 | 7 | 6 | 8 |
| 1 | 5 | 9 | 9 | 4 | 6 | 5 | 7 | 9 | 6 |
| 1 | Total | 35 | 35 | 25 | 31 | 30 | 31 | 34 | 34 |
| 1 | Average | 7.0 | 7.0 | 5.0 | 6.2 | 6.0 | 6.2 | 6.8 | 6.8 |
| 7 | 1 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 7 |
| 7 | 2 | 6 | 7 | 7 | 8 | 6 | 4 | 5 | 6 |
| 7 | 3 | 6 | 6 | 5 | 5 | 6 | 6 | 5 | 6 |
| 7 | 4 | 8 | 6 | 6 | 6 | 7 | 8 | 7 | 7 |
| 7 | 5 | 7 | 8 | 6 | 7 | 7 | 8 | 7 | 7 |
| 7 | Total | 34 | 34 | 31 | 32 | 32 | 32 | 30 | 33 |
| 7 | Average | 6.8 | 6.8 | 6.2 | 6.4 | 6.4 | 6.4 | 6.0 | 6.6 |
| 14 | 1 | 6 | 7 | 7 | 7 | 7 | 7 | 6 | 7 |
| 14 | 2 | 6 | 8 | 4 | 6 | 6 | 6 | 5 | 6 |
| 14 | 3 | 6 | 5 | 7 | 5 | 6 | 6 | 5 | 6 |
| 14 | 4 | 7 | 7 | 6 | 7 | 6 | 7 | 7 | 7 |
| 14 | 5 | 8 | 8 | 7 | 7 | 6 | 6 | 8 | 7 |
| 14 | Total | 33 | 35 | 31 | 32 | 31 | 32 | 31 | 33 |
| 14 | Average | 6.6 | 7.0 | 6.2 | 6.4 | 6.2 | 6.4 | 6.2 | 6.6 |
| 21 | 1 | 7 | 8 | 7 | 6 | 7 | 8 | 8 | 7 |
| 21 | 2 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 21 | 3 | 5 | 6 | 5 | 6 | 6 | 6 | 6 | 5 |
| 21 | 4 | 6 | 7 | 5 | 6 | 7 | 7 | 7 | 6 |
| 21 | 5 | 6 | 7 | 8 | 6 | 7 | 8 | 7 | 6 |
| 21 | Total | 30 | 35 | 32 | 31 | 34 | 36 | 35 | 31 |
| 21 | Average | 6.0 | 7.0 | 6.4 | 6.2 | 6.8 | 7.2 | 7.0 | 6.2 |

Replication 2

| Store days | Panellist | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 7 | 6 | 5 | 7 | 6 | 7 | 6 | 8 |
| 1 | 2 | 7 | 6 | 4 | 5 | 5 | 4 | 6 | 6 |
| 1 | 3 | 6 | 6 | 4 | 6 | 4 | 6 | 8 | 6 |
| 1 | 4 | 8 | 8 | 4 | 8 | 8 | 5 | 6 | 7 |
| 1 | 5 | 9 | 9 | 4 | 6 | 5 | 7 | 9 | 6 |
| 1 | Total | 37 | 35 | 21 | 32 | 28 | 29 | 35 | 33 |
| 1 | Average | 7.4 | 7.0 | 4.2 | 6.4 | 5.6 | 5.8 | 7.0 | 6.6 |
| 7 | 1 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 5 |
| 7 | 2 | 6 | 7 | 6 | 8 | 6 | 4 | 5 | 6 |
| 7 | 3 | 6 | 6 | 5 | 7 | 6 | 7 | 8 | 6 |
| 7 | 4 | 7 | 7 | 6 | 6 | 6 | 8 | 7 | 6 |
| 7 | 5 | 7 | 8 | 6 | 7 | 7 | 8 | 7 | 7 |
| 7 | Total | 33 | 35 | 30 | 34 | 31 | 33 | 33 | 30 |
| 7 | Average | 6.6 | 7.0 | 6.0 | 6.8 | 6.2 | 6.6 | 6.6 | 6.0 |
| 14 | 1 | 6 | 7 | 7 | 7 | 7 | 7 | 6 | 7 |
| 14 | 2 | 6 | 8 | 4 | 6 | 6 | 6 | 5 | 6 |
| 14 | 3 | 6 | 7 | 7 | 7 | 5 | 6 | 7 | 6 |
| 14 | 4 | 7 | 7 | 6 | 7 | 6 | 6 | 7 | 6 |
| 14 | 5 | 8 | 8 | 7 | 7 | 6 | 6 | 8 | 7 |
| 14 | Total | 33 | 37 | 31 | 34 | 30 | 31 | 33 | 32 |
| 14 | Average | 6.6 | 7.4 | 6.2 | 6.8 | 6.0 | 6.2 | 6.6 | 6.4 |
| 21 | 1 | 4 | 8 | 7 | 6 | 7 | 8 | 8 | 6 |
| 21 | 2 | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 6 |
| 21 | 3 | 5 | 6 | 5 | 6 | 8 | 6 | 6 | 5 |
| 21 | 4 | 6 | 7 | 7 | 6 | 7 | 5 | 5 | 6 |
| 21 | 5 | 6 | 5 | 8 | 5 | 7 | 7 | 7 | 6 |
| 21 | Total | 27 | 32 | 34 | 30 | 36 | 33 | 33 | 29 |
| 21 | Average | 5.4 | 6.4 | 6.8 | 6.0 | 7.2 | 6.6 | 6.6 | 5.8 |

Replication 3

| Store days | Panellist | Appearance | Aroma | Sourness | Sweetness | Flavour | Mouth feel | After-taste | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 7 | 6 | 6 | 7 | 8 | 7 | 6 | 8 |
| 1 | 2 | 5 | 6 | 6 | 5 | 6 | 6 | 6 | 6 |
| 1 | 3 | 7 | 6 | 7 | 6 | 5 | 6 | 7 | 7 |
| 1 | 4 | 8 | 8 | 6 | 6 | 7 | 7 | 6 | 8 |
| 1 | 5 | 6 | 9 | 4 | 6 | 6 | 7 | 8 | 6 |
| 1 | Total | 33 | 35 | 29 | 30 | 32 | 33 | 33 | 35 |
| 1 | Average | 6.6 | 7.0 | 5.8 | 6.0 | 6.4 | 6.6 | 6.6 | 7.0 |
| 7 | 1 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 7 |
| 7 | 2 | 6 | 7 | 7 | 6 | 6 | 4 | 5 | 7 |
| 7 | 3 | 7 | 6 | 5 | 5 | 7 | 6 | 5 | 8 |
| 7 | 4 | 8 | 6 | 6 | 6 | 7 | 7 | 5 | 7 |
| 7 | 5 | 7 | 7 | 6 | 7 | 7 | 8 | 6 | 7 |
| 7 | Total | 35 | 33 | 30 | 30 | 33 | 31 | 27 | 36 |
| 7 | Average | 7.0 | 6.6 | 6.0 | 6.0 | 6.6 | 6.2 | 5.4 | 7.2 |
| 14 | 1 | 6 | 7 | 7 | 7 | 7 | 7 | 6 | 7 |
| 14 | 2 | 6 | 6 | 4 | 6 | 6 | 6 | 5 | 6 |
| 14 | 3 | 6 | 5 | 7 | 5 | 7 | 7 | 5 | 7 |
| 14 | 4 | 7 | 7 | 6 | 7 | 6 | 7 | 5 | 7 |
| 14 | 5 | 8 | 8 | 7 | 5 | 6 | 6 | 8 | 7 |
| 14 | Total | 33 | 33 | 31 | 30 | 32 | 33 | 29 | 34 |
| 14 | Average | 6.6 | 6.6 | 6.2 | 6.0 | 6.4 | 6.6 | 5.8 | 6.8 |
| 21 | 1 | 7 | 8 | 7 | 6 | 7 | 8 | 8 | 7 |
| 21 | 2 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 21 | 3 | 8 | 8 | 5 | 6 | 6 | 8 | 7 | 7 |
| 21 | 4 | 6 | 8 | 5 | 6 | 5 | 8 | 8 | 6 |
| 21 | 5 | 6 | 7 | 6 | 7 | 7 | 8 | 7 | 6 |
| 21 | Total | 33 | 38 | 30 | 32 | 32 | 39 | 37 | 33 |
| 21 | Average | 6.6 | 7.6 | 6.0 | 6.4 | 6.4 | 7.8 | 7.4 | 6.6 |

## Appendix E. Statistical output

## E.1 Statistical output phase 1: Commercial pea protein powder purification

E.1.1 Statistical analysis of description of colour of refined commercial pea protein powder

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| L | Commercial pea protein powder | 3 | 76.8833 | .10970 | .06333 | 76.6108 | 77.1558 | 76.76 | 76.97 |
| | Refined pea protein paste | 3 | 81.1433 | .76166 | .43975 | 79.2513 | 83.0354 | 80.27 | 81.67 |
| | Total | 6 | 79.0133 | 2.38352 | .97307 | 76.5120 | 81.5147 | 76.76 | 81.67 |
| a | Commercial pea protein powder | 3 | 3.0800 | .01732 | .01000 | 3.0370 | 3.1230 | 3.06 | 3.09 |
| | Refined pea protein paste | 3 | .3500 | .06245 | .03606 | .1949 | .5051 | .30 | .42 |
| | Total | 6 | 1.7150 | 1.49584 | .61068 | .1452 | 3.2848 | .30 | 3.09 |
| b | Commercial pea protein powder | 3 | 16.3233 | .09018 | .05207 | 16.0993 | 16.5474 | 16.23 | 16.41 |
| | Refined pea protein paste | 3 | 6.8600 | .11533 | .06658 | 6.5735 | 7.1465 | 6.77 | 6.99 |
| | Total | 6 | 11.5917 | 5.18411 | 2.11640 | 6.1513 | 17.0321 | 6.77 | 16.41 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| L | 10.197 | 1 | 4 | .033 |
| a | 5.000 | 1 | 4 | .089 |
| b | .411 | 1 | 4 | .556 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| L | Between Groups | 27.221 | 1 | 27.221 | 91.938 | .001 |
| | Within Groups | 1.184 | 4 | .296 | | |
| | Total | 28.406 | 5 | | | |
| a | Between Groups | 11.179 | 1 | 11.179 | 5323.500 | .000 |
| | Within Groups | .008 | 4 | .002 | | |
| | Total | 11.188 | 5 | | | |
| b | Between Groups | 134.332 | 1 | 134.332 | 12534.869 | .000 |
| | Within Groups | .043 | 4 | .011 | | |
| | Total | 134.375 | 5 | | | |

## E.1.2 Statistical analysis of protein content of refined pea protein

**Descriptives**

Protein concentration （%）

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Commercial pea protein powder | 3 | 77.4400 | .56000 | .32332 | 76.0489 | 78.8311 | 76.88 | 78.00 |
| Refined pea protein paste | 3 | 17.3100 | .32000 | .18475 | 16.5151 | 18.1049 | 16.99 | 17.63 |
| Refining pea protein paste (dry matter) | 3 | 92.9633 | 1.19559 | .69027 | 89.9933 | 95.9333 | 91.87 | 94.24 |
| Total | 9 | 62.5711 | 34.61161 | 11.53720 | 35.9663 | 89.1759 | 16.99 | 94.24 |

**Test of Homogeneity of Variances**

Protein concentration （%）

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| 2.058 | 2 | 6 | .209 |

**ANOVA**

Protein concentration （%）

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 9580.018 | 2 | 4790.009 | 7786.803 | .000 |
| Within Groups | 3.691 | 6 | .615 | | |
| Total | 9583.708 | 8 | | | |

**Multiple Comparisons**

Dependent Variable: Protein concentration (%) LSD

| (I) Different pea protein | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Commercial pea protein powder | Refined pea protein paste | 60.13000* | .64039 | .000 | 58.5630 | 61.6970 |
| | Refined pea protein paste (dry matter) | -15.52333* | .64039 | .000 | -17.0903 | -13.9564 |
| Refined pea protein paste | Commercial pea protein powder | -60.13000* | .64039 | .000 | -61.6970 | -58.5630 |
| | Refined pea protein paste (dry matter) | -75.65333* | .64039 | .000 | -77.2203 | -74.0864 |
| Refined pea protein paste (dry matter) | Commercial pea protein powder | 15.52333* | .64039 | .000 | 13.9564 | 17.0903 |
| | Refined pea protein paste | 75.65333* | .64039 | .000 | 74.0864 | 77.2203 |

*. The mean difference is significant at the 0.05 level.

## E.2 Statistical output phase 2: Development of fermented pea protein-coconut milk beverage

### E.2.1 Statistical analysis of the pH of coconut milk fermentation by different temperatures

**Between-Subjects Factors**

| | | N |
|---|---|---|
| Time (h) | 0 | 15 |
| | 2 | 15 |
| | 4 | 15 |
| | 6 | 15 |
| | 8 | 15 |
| | 10 | 15 |
| | 12 | 15 |
| Temperature (℃) | 35 | 21 |
| | 37 | 21 |
| | 40 | 21 |
| | 43 | 21 |
| | 45 | 21 |

**Levene's Test of Equality of Error Variances**[a]

Dependent Variable: pH

| F | df1 | df2 | Sig. |
|---|---|---|---|
| .908 | 34 | 70 | .613 |

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Time + Temperature + Time * Temperature

**Tests of Between-Subjects Effects**

Dependent Variable: pH

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 68.218[a] | 34 | 2.006 | 773.967 | .000 |
| Intercept | 2470.542 | 1 | 2470.542 | 953000.964 | .000 |
| Time | 65.132 | 6 | 10.855 | 4187.389 | .000 |
| Temperature | 2.271 | 4 | .568 | 219.036 | .000 |
| Time * Temperature | .815 | 24 | .034 | 13.100 | .000 |
| Error | .181 | 70 | .003 | | |
| Total | 2538.941 | 105 | | | |
| Corrected Total | 68.400 | 104 | | | |

a. R Squared = .997 (Adjusted R Squared = .996)

**Descriptive Statistics**

Dependent Variable: pH

| Time (h) | Temperature (℃) | Mean | Std. Deviation | N |
|---|---|---|---|---|
| 0 | 35 | 6.2000 | 0.00000 | 3 |
| | 37 | 6.2000 | 0.00000 | 3 |
| | 40 | 6.2000 | 0.00000 | 3 |
| | 43 | 6.2000 | 0.00000 | 3 |
| | 45 | 6.2000 | 0.00000 | 3 |
| | Total | 6.2000 | 0.00000 | 15 |
| 2 | 35 | 6.0900 | .03000 | 3 |
| | 37 | 6.0300 | .02000 | 3 |
| | 40 | 5.7500 | .04000 | 3 |
| | 43 | 5.7100 | .02000 | 3 |
| | 45 | 5.6200 | .04000 | 3 |
| | Total | 5.8400 | .19380 | 15 |
| 4 | 35 | 5.2100 | .05000 | 3 |
| | 37 | 5.1500 | .06000 | 3 |
| | 40 | 5.0500 | .05000 | 3 |
| | 43 | 4.5700 | .08000 | 3 |
| | 45 | 4.5500 | .05000 | 3 |
| | Total | 4.9060 | .30142 | 15 |
| 6 | 35 | 4.7400 | .04000 | 3 |
| | 37 | 4.6600 | .05000 | 3 |
| | 40 | 4.5600 | .08000 | 3 |
| | 43 | 4.2800 | .06000 | 3 |
| | 45 | 4.2500 | .04000 | 3 |
| | Total | 4.4980 | .21119 | 15 |
| 8 | 35 | 4.4900 | .05000 | 3 |
| | 37 | 4.3900 | .03000 | 3 |
| | 40 | 4.3600 | .06000 | 3 |
| | 43 | 4.1300 | .04000 | 3 |
| | 45 | 4.0800 | .05000 | 3 |
| | Total | 4.2900 | .16818 | 15 |
| 10 | 35 | 4.3000 | .07000 | 3 |
| | 37 | 4.2500 | .06000 | 3 |
| | 40 | 4.2100 | .08000 | 3 |
| | 43 | 4.0500 | .05000 | 3 |
| | 45 | 3.9833 | .06506 | 3 |
| | Total | 4.1587 | .13726 | 15 |
| 12 | 35 | 4.1900 | .07000 | 3 |
| | 37 | 4.1300 | .05000 | 3 |
| | 40 | 4.0900 | .06000 | 3 |
| | 43 | 3.9800 | .08000 | 3 |
| | 45 | 3.9200 | .05000 | 3 |
| | Total | 4.0620 | .11521 | 15 |
| Total | 35 | 5.0314 | .78905 | 21 |
| | 37 | 4.9729 | .80632 | 21 |
| | 40 | 4.8886 | .77358 | 21 |
| | 43 | 4.7029 | .84348 | 21 |
| | 45 | 4.6576 | .85075 | 21 |
| | Total | 4.8507 | .81098 | 105 |

**1. Time * Temperature**

Dependent Variable: pH

| Time (h) | Temperature (℃) | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| 0 | 35 | 6.200 | .029 | 6.141 | 6.259 |
| | 37 | 6.200 | .029 | 6.141 | 6.259 |
| | 40 | 6.200 | .029 | 6.141 | 6.259 |
| | 43 | 6.200 | .029 | 6.141 | 6.259 |
| | 45 | 6.200 | .029 | 6.141 | 6.259 |
| 2 | 35 | 6.090 | .029 | 6.031 | 6.149 |
| | 37 | 6.030 | .029 | 5.971 | 6.089 |
| | 40 | 5.750 | .029 | 5.691 | 5.809 |
| | 43 | 5.710 | .029 | 5.651 | 5.769 |
| | 45 | 5.620 | .029 | 5.561 | 5.679 |
| 4 | 35 | 5.210 | .029 | 5.151 | 5.269 |
| | 37 | 5.150 | .029 | 5.091 | 5.209 |
| | 40 | 5.050 | .029 | 4.991 | 5.109 |
| | 43 | 4.570 | .029 | 4.511 | 4.629 |
| | 45 | 4.550 | .029 | 4.491 | 4.609 |
| 6 | 35 | 4.740 | .029 | 4.681 | 4.799 |
| | 37 | 4.660 | .029 | 4.601 | 4.719 |
| | 40 | 4.560 | .029 | 4.501 | 4.619 |
| | 43 | 4.280 | .029 | 4.221 | 4.339 |
| | 45 | 4.250 | .029 | 4.191 | 4.309 |
| 8 | 35 | 4.490 | .029 | 4.431 | 4.549 |
| | 37 | 4.390 | .029 | 4.331 | 4.449 |
| | 40 | 4.360 | .029 | 4.301 | 4.419 |
| | 43 | 4.130 | .029 | 4.071 | 4.189 |
| | 45 | 4.080 | .029 | 4.021 | 4.139 |
| 10 | 35 | 4.300 | .029 | 4.241 | 4.359 |
| | 37 | 4.250 | .029 | 4.191 | 4.309 |
| | 40 | 4.210 | .029 | 4.151 | 4.269 |
| | 43 | 4.050 | .029 | 3.991 | 4.109 |
| | 45 | 3.983 | .029 | 3.925 | 4.042 |
| 12 | 35 | 4.190 | .029 | 4.131 | 4.249 |
| | 37 | 4.130 | .029 | 4.071 | 4.189 |
| | 40 | 4.090 | .029 | 4.031 | 4.149 |
| | 43 | 3.980 | .029 | 3.921 | 4.039 |
| | 45 | 3.920 | .029 | 3.861 | 3.979 |

**2. Time**

Dependent Variable: pH

| Time (h) | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 0 | 6.200 | .013 | 6.174 | 6.226 |
| 2 | 5.840 | .013 | 5.814 | 5.866 |
| 4 | 4.906 | .013 | 4.880 | 4.932 |
| 6 | 4.498 | .013 | 4.472 | 4.524 |
| 8 | 4.290 | .013 | 4.264 | 4.316 |
| 10 | 4.159 | .013 | 4.132 | 4.185 |
| 12 | 4.062 | .013 | 4.036 | 4.088 |

**3. Temperature**

Dependent Variable: pH

| Temperature (℃) | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 35 | 5.031 | .011 | 5.009 | 5.054 |
| 37 | 4.973 | .011 | 4.951 | 4.995 |
| 40 | 4.889 | .011 | 4.866 | 4.911 |
| 43 | 4.703 | .011 | 4.681 | 4.725 |
| 45 | 4.658 | .011 | 4.635 | 4.680 |

**Multiple Comparisons**

Dependent Variable: pH

LSD

| (I) Temperature (℃) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 35 | 37 | .0586* | .01571 | .000 | .0272 | .0899 |
| | 40 | .1429* | .01571 | .000 | .1115 | .1742 |
| | 43 | .3286* | .01571 | .000 | .2972 | .3599 |
| | 45 | .3738* | .01571 | .000 | .3425 | .4051 |
| 37 | 35 | -.0586* | .01571 | .000 | -.0899 | -.0272 |
| | 40 | .0843* | .01571 | .000 | .0529 | .1156 |
| | 43 | .2700* | .01571 | .000 | .2387 | .3013 |
| | 45 | .3152* | .01571 | .000 | .2839 | .3466 |
| 40 | 35 | -.1429* | .01571 | .000 | -.1742 | -.1115 |
| | 37 | -.0843* | .01571 | .000 | -.1156 | -.0529 |
| | 43 | .1857* | .01571 | .000 | .1544 | .2171 |
| | 45 | .2310* | .01571 | .000 | .1996 | .2623 |
| 43 | 35 | -.3286* | .01571 | .000 | -.3599 | -.2972 |
| | 37 | -.2700* | .01571 | .000 | -.3013 | -.2387 |
| | 40 | -.1857* | .01571 | .000 | -.2171 | -.1544 |
| | 45 | .0452* | .01571 | .005 | .0139 | .0766 |
| 45 | 35 | -.3738* | .01571 | .000 | -.4051 | -.3425 |
| | 37 | -.3152* | .01571 | .000 | -.3466 | -.2839 |
| | 40 | -.2310* | .01571 | .000 | -.2623 | -.1996 |
| | 43 | -.0452* | .01571 | .005 | -.0766 | -.0139 |

Based on observed means.

The error term is Mean Square (Error) = .003.

*. The mean difference is significant at the .05 level.

**Multiple Comparisons**

Dependent Variable: pH

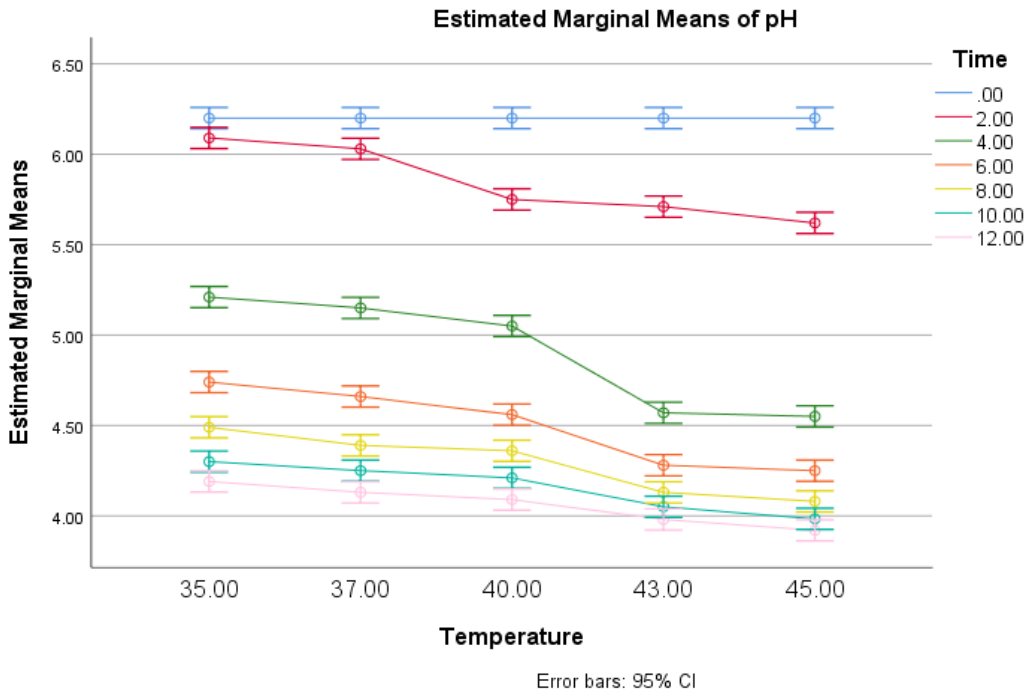
LSD

| (I) Time (h) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0 | 2 | .3600* | .01859 | .000 | .3229 | .3971 |
| | 4 | 1.2940* | .01859 | .000 | 1.2569 | 1.3311 |
| | 6 | 1.7020* | .01859 | .000 | 1.6649 | 1.7391 |
| | 8 | 1.9100* | .01859 | .000 | 1.8729 | 1.9471 |
| | 10 | 2.0413* | .01859 | .000 | 2.0043 | 2.0784 |
| | 12 | 2.1380* | .01859 | .000 | 2.1009 | 2.1751 |
| 2 | 0 | -.3600* | .01859 | .000 | -.3971 | -.3229 |
| | 4 | .9340* | .01859 | .000 | .8969 | .9711 |
| | 6 | 1.3420* | .01859 | .000 | 1.3049 | 1.3791 |
| | 8 | 1.5500* | .01859 | .000 | 1.5129 | 1.5871 |
| | 10 | 1.6813* | .01859 | .000 | 1.6443 | 1.7184 |
| | 12 | 1.7780* | .01859 | .000 | 1.7409 | 1.8151 |
| 4 | 0 | -1.2940* | .01859 | .000 | -1.3311 | -1.2569 |
| | 2 | -.9340* | .01859 | .000 | -.9711 | -.8969 |
| | 6 | .4080* | .01859 | .000 | .3709 | .4451 |
| | 8 | .6160* | .01859 | .000 | .5789 | .6531 |
| | 10 | .7473* | .01859 | .000 | .7103 | .7844 |
| | 12 | .8440* | .01859 | .000 | .8069 | .8811 |
| 6 | 0 | -1.7020* | .01859 | .000 | -1.7391 | -1.6649 |
| | 2 | -1.3420* | .01859 | .000 | -1.3791 | -1.3049 |
| | 4 | -.4080* | .01859 | .000 | -.4451 | -.3709 |
| | 8 | .2080* | .01859 | .000 | .1709 | .2451 |
| | 10 | .3393* | .01859 | .000 | .3023 | .3764 |
| | 12 | .4360* | .01859 | .000 | .3989 | .4731 |
| 8 | 0 | -1.9100* | .01859 | .000 | -1.9471 | -1.8729 |
| | 2 | -1.5500* | .01859 | .000 | -1.5871 | -1.5129 |
| | 4 | -.6160* | .01859 | .000 | -.6531 | -.5789 |
| | 6 | -.2080* | .01859 | .000 | -.2451 | -.1709 |
| | 10 | .1313* | .01859 | .000 | .0943 | .1684 |
| | 12 | .2280* | .01859 | .000 | .1909 | .2651 |
| 10 | 0 | -2.0413* | .01859 | .000 | -2.0784 | -2.0043 |
| | 2 | -1.6813* | .01859 | .000 | -1.7184 | -1.6443 |
| | 4 | -.7473* | .01859 | .000 | -.7844 | -.7103 |
| | 6 | -.3393* | .01859 | .000 | -.3764 | -.3023 |
| | 8 | -.1313* | .01859 | .000 | -.1684 | -.0943 |
| | 12 | .0967* | .01859 | .000 | .0596 | .1337 |
| 12 | 0 | -2.1380* | .01859 | .000 | -2.1751 | -2.1009 |
| | 2 | -1.7780* | .01859 | .000 | -1.8151 | -1.7409 |
| | 4 | -.8440* | .01859 | .000 | -.8811 | -.8069 |
| | 6 | -.4360* | .01859 | .000 | -.4731 | -.3989 |
| | 8 | -.2280* | .01859 | .000 | -.2651 | -.1909 |
| | 10 | -.0967* | .01859 | .000 | -.1337 | -.0596 |

Based on observed means.

The error term is Mean Square (Error) = .003.

*. The mean difference is significant at the .05 level.




E.2.2 Statistical analysis of the pH of pea protein paste and coconut milk fermentation by different pea protein paste concentration

**Between-Subjects Factors**

| | | N |
|---|---|---|
| Time (h) | 0 | 15 |
| | 2 | 15 |
| | 4 | 15 |
| | 6 | 15 |
| | 8 | 15 |
| | 10 | 15 |
| | 12 | 15 |
| Concentration (%) | 3 | 21 |
| | 5 | 21 |
| | 7 | 21 |
| | 9 | 21 |
| | 11 | 21 |

**Tests of Between-Subjects Effects**

Dependent Variable: pH

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 56.303[a] | 34 | 1.656 | 496.933 | .000 |
| Intercept | 2535.968 | 1 | 2535.968 | 761007.832 | .000 |
| Time | 56.079 | 6 | 9.347 | 2804.771 | .000 |
| Concentration | .092 | 4 | .023 | 6.897 | .000 |
| Time * Concentration | .132 | 24 | .005 | 1.646 | .056 |
| Error | .233 | 70 | .003 | | |
| Total | 2592.504 | 105 | | | |
| Corrected Total | 56.536 | 104 | | | |

a. R Squared = .996 (Adjusted R Squared = .994)

**Descriptive Statistics**

Dependent Variable: pH

| Time (h) | Concentration (%) | Mean | Std. Deviation | N |
|---|---|---|---|---|
| 0 | 3 | 6.2000 | 0.00000 | 3 |
| | 5 | 6.2000 | 0.00000 | 3 |
| | 7 | 6.2000 | 0.00000 | 3 |
| | 9 | 6.2000 | 0.00000 | 3 |
| | 11 | 6.2000 | 0.00000 | 3 |
| | Total | 6.2000 | 0.00000 | 15 |
| 2 | 3 | 5.7600 | .03000 | 3 |
| | 5 | 5.7500 | .02000 | 3 |
| | 7 | 5.7100 | .04000 | 3 |
| | 9 | 5.6600 | .02000 | 3 |
| | 11 | 5.7000 | .03000 | 3 |
| | Total | 5.7160 | .04469 | 15 |
| 4 | 3 | 5.0800 | .05000 | 3 |
| | 5 | 5.0500 | .06000 | 3 |
| | 7 | 5.1100 | .05000 | 3 |
| | 9 | 5.1500 | .03000 | 3 |
| | 11 | 5.1200 | .05000 | 3 |
| | Total | 5.1020 | .05454 | 15 |
| 6 | 3 | 4.5300 | .04000 | 3 |
| | 5 | 4.5600 | .05000 | 3 |
| | 7 | 4.6300 | .03000 | 3 |
| | 9 | 4.6500 | .06000 | 3 |
| | 11 | 4.6400 | .04000 | 3 |
| | Total | 4.6020 | .06259 | 15 |
| 8 | 3 | 4.3000 | .05000 | 3 |
| | 5 | 4.3600 | .03000 | 3 |
| | 7 | 4.3800 | .06000 | 3 |
| | 9 | 4.4200 | .04000 | 3 |
| | 11 | 4.4300 | .05000 | 3 |
| | Total | 4.3780 | .06259 | 15 |
| 10 | 3 | 4.2100 | .21794 | 3 |
| | 5 | 4.2100 | .03000 | 3 |
| | 7 | 4.2500 | .06000 | 3 |
| | 9 | 4.3000 | .04000 | 3 |
| | 11 | 4.3300 | .05000 | 3 |
| | Total | 4.2600 | .10247 | 15 |
| 12 | 3 | 4.0467 | .07506 | 3 |
| | 5 | 4.0900 | .06000 | 3 |
| | 7 | 4.1300 | .08000 | 3 |
| | 9 | 4.1900 | .05000 | 3 |
| | 11 | 4.2600 | .07000 | 3 |
| | Total | 4.1433 | .09656 | 15 |
| Total | 3 | 4.8752 | .79366 | 21 |
| | 5 | 4.8886 | .77280 | 21 |
| | 7 | 4.9157 | .75096 | 21 |
| | 9 | 4.9386 | .72289 | 21 |
| | 11 | 4.9543 | .71317 | 21 |
| | Total | 4.9145 | .73730 | 105 |

**Levene's Test of Equality of Error Variancesa**

**Dependent Variable: pH**

| F | df1 | df2 | Sig. |
|---|---|---|---|
| 2.822 | 34 | 70 | .000 |

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Time + Concentration + Time * Concentration

**1. Time**

Dependent Variable: pH

| Time (h) | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 0 | 6.200 | .015 | 6.170 | 6.230 |
| 2 | 5.716 | .015 | 5.686 | 5.746 |
| 4 | 5.102 | .015 | 5.072 | 5.132 |
| 6 | 4.602 | .015 | 4.572 | 4.632 |
| 8 | 4.378 | .015 | 4.348 | 4.408 |
| 10 | 4.260 | .015 | 4.230 | 4.290 |
| 12 | 4.143 | .015 | 4.114 | 4.173 |

**2. Time * Concentration**

Dependent Variable: pH

| Time (h) | Concentration (%) | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| 0 | 3 | 6.200 | .033 | 6.134 | 6.266 |
| | 5 | 6.200 | .033 | 6.134 | 6.266 |
| | 7 | 6.200 | .033 | 6.134 | 6.266 |
| | 9 | 6.200 | .033 | 6.134 | 6.266 |
| | 11 | 6.200 | .033 | 6.134 | 6.266 |
| 2 | 3 | 5.760 | .033 | 5.694 | 5.826 |
| | 5 | 5.750 | .033 | 5.684 | 5.816 |
| | 7 | 5.710 | .033 | 5.644 | 5.776 |
| | 9 | 5.660 | .033 | 5.594 | 5.726 |
| | 11 | 5.700 | .033 | 5.634 | 5.766 |
| 4 | 3 | 5.080 | .033 | 5.014 | 5.146 |
| | 5 | 5.050 | .033 | 4.984 | 5.116 |
| | 7 | 5.110 | .033 | 5.044 | 5.176 |
| | 9 | 5.150 | .033 | 5.084 | 5.216 |
| | 11 | 5.120 | .033 | 5.054 | 5.186 |
| 6 | 3 | 4.530 | .033 | 4.464 | 4.596 |
| | 5 | 4.560 | .033 | 4.494 | 4.626 |
| | 7 | 4.630 | .033 | 4.564 | 4.696 |
| | 9 | 4.650 | .033 | 4.584 | 4.716 |
| | 11 | 4.640 | .033 | 4.574 | 4.706 |
| 8 | 3 | 4.300 | .033 | 4.234 | 4.366 |
| | 5 | 4.360 | .033 | 4.294 | 4.426 |
| | 7 | 4.380 | .033 | 4.314 | 4.446 |
| | 9 | 4.420 | .033 | 4.354 | 4.486 |
| | 11 | 4.430 | .033 | 4.364 | 4.496 |
| 10 | 3 | 4.210 | .033 | 4.144 | 4.276 |
| | 5 | 4.210 | .033 | 4.144 | 4.276 |
| | 7 | 4.250 | .033 | 4.184 | 4.316 |
| | 9 | 4.300 | .033 | 4.234 | 4.366 |
| | 11 | 4.330 | .033 | 4.264 | 4.396 |
| 12 | 3 | 4.047 | .033 | 3.980 | 4.113 |
| | 5 | 4.090 | .033 | 4.024 | 4.156 |
| | 7 | 4.130 | .033 | 4.064 | 4.196 |
| | 9 | 4.190 | .033 | 4.124 | 4.256 |
| | 11 | 4.260 | .033 | 4.194 | 4.326 |

**3. Concentration**

Dependent Variable: pH

| Concentration (%) | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 3 | 4.875 | .013 | 4.850 | 4.900 |
| 5 | 4.889 | .013 | 4.863 | 4.914 |
| 7 | 4.916 | .013 | 4.891 | 4.941 |
| 9 | 4.939 | .013 | 4.913 | 4.964 |
| 11 | 4.954 | .013 | 4.929 | 4.979 |

**Multiple Comparisons**

Dependent Variable: pH

LSD

| (I) Time (h) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0 | 2 | .4840* | .02108 | .000 | .4420 | .5260 |
| | 4 | 1.0980* | .02108 | .000 | 1.0560 | 1.1400 |
| | 6 | 1.5980* | .02108 | .000 | 1.5560 | 1.6400 |
| | 8 | 1.8220* | .02108 | .000 | 1.7800 | 1.8640 |
| | 10 | 1.9400* | .02108 | .000 | 1.8980 | 1.9820 |
| | 12 | 2.0567* | .02108 | .000 | 2.0146 | 2.0987 |
| 2 | 0 | -.4840* | .02108 | .000 | -.5260 | -.4420 |
| | 4 | .6140* | .02108 | .000 | .5720 | .6560 |
| | 6 | 1.1140* | .02108 | .000 | 1.0720 | 1.1560 |
| | 8 | 1.3380* | .02108 | .000 | 1.2960 | 1.3800 |
| | 10 | 1.4560* | .02108 | .000 | 1.4140 | 1.4980 |
| | 12 | 1.5727* | .02108 | .000 | 1.5306 | 1.6147 |
| 4 | 0 | -1.0980* | .02108 | .000 | -1.1400 | -1.0560 |
| | 2 | -.6140* | .02108 | .000 | -.6560 | -.5720 |
| | 6 | .5000* | .02108 | .000 | .4580 | .5420 |
| | 8 | .7240* | .02108 | .000 | .6820 | .7660 |
| | 10 | .8420* | .02108 | .000 | .8000 | .8840 |
| | 12 | .9587* | .02108 | .000 | .9166 | 1.0007 |
| 6 | 0 | -1.5980* | .02108 | .000 | -1.6400 | -1.5560 |
| | 2 | -1.1140* | .02108 | .000 | -1.1560 | -1.0720 |
| | 4 | -.5000* | .02108 | .000 | -.5420 | -.4580 |
| | 8 | .2240* | .02108 | .000 | .1820 | .2660 |
| | 10 | .3420* | .02108 | .000 | .3000 | .3840 |
| | 12 | .4587* | .02108 | .000 | .4166 | .5007 |
| 8 | 0 | -1.8220* | .02108 | .000 | -1.8640 | -1.7800 |
| | 2 | -1.3380* | .02108 | .000 | -1.3800 | -1.2960 |
| | 4 | -.7240* | .02108 | .000 | -.7660 | -.6820 |
| | 6 | -.2240* | .02108 | .000 | -.2660 | -.1820 |
| | 10 | .1180* | .02108 | .000 | .0760 | .1600 |
| | 12 | .2347* | .02108 | .000 | .1926 | .2767 |
| 10 | 0 | -1.9400* | .02108 | .000 | -1.9820 | -1.8980 |
| | 2 | -1.4560* | .02108 | .000 | -1.4980 | -1.4140 |
| | 4 | -.8420* | .02108 | .000 | -.8840 | -.8000 |
| | 6 | -.3420* | .02108 | .000 | -.3840 | -.3000 |
| | 8 | -.1180* | .02108 | .000 | -.1600 | -.0760 |
| | 12 | .1167* | .02108 | .000 | .0746 | .1587 |
| 12 | 0 | -2.0567* | .02108 | .000 | -2.0987 | -2.0146 |
| | 2 | -1.5727* | .02108 | .000 | -1.6147 | -1.5306 |
| | 4 | -.9587* | .02108 | .000 | -1.0007 | -.9166 |
| | 6 | -.4587* | .02108 | .000 | -.5007 | -.4166 |
| | 8 | -.2347* | .02108 | .000 | -.2767 | -.1926 |
| | 10 | -.1167* | .02108 | .000 | -.1587 | -.0746 |

Based on observed means.

The error term is Mean Square (Error) = .003.

*. The mean difference is significant at the .05 level.

**Multiple Comparisons**

Dependent Variable: pH

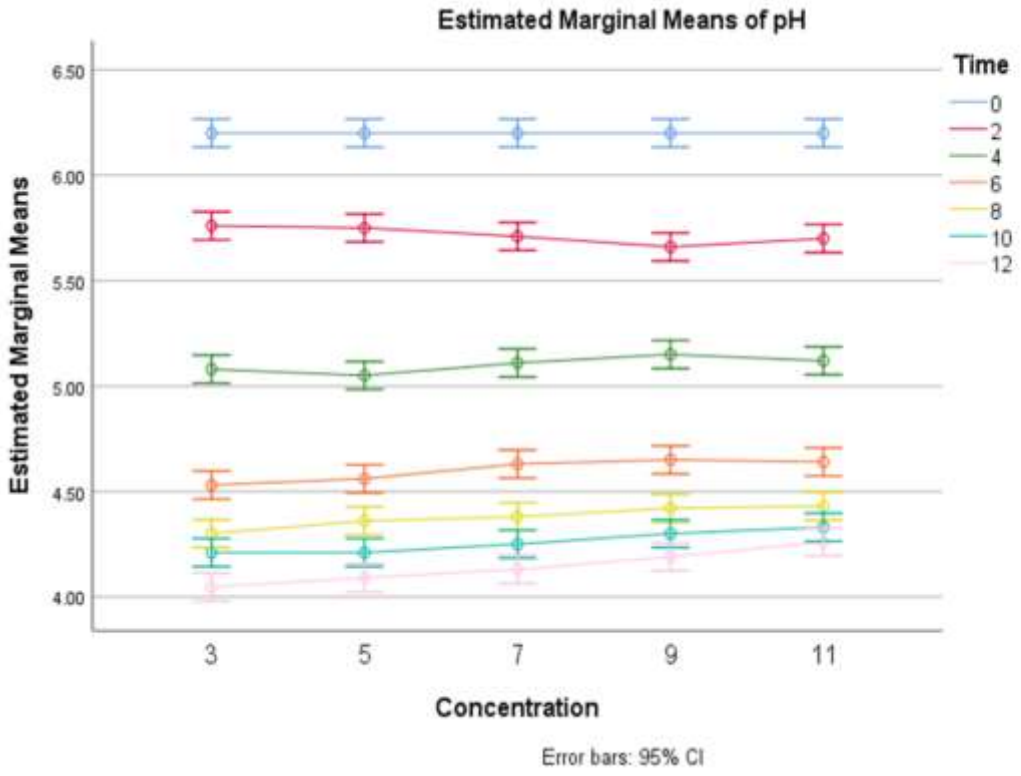
LSD

| (I) Concentration (%) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 3 | 5 | -.0133 | .01781 | .457 | -.0489 | .0222 |
| | 7 | -.0405* | .01781 | .026 | -.0760 | -.0049 |
| | 9 | -.0633* | .01781 | .001 | -.0989 | -.0278 |
| | 11 | -.0790* | .01781 | .000 | -.1146 | -.0435 |
| 5 | 3 | .0133 | .01781 | .457 | -.0222 | .0489 |
| | 7 | -.0271 | .01781 | .132 | -.0627 | .0084 |
| | 9 | -.0500* | .01781 | .006 | -.0855 | -.0145 |
| | 11 | -.0657* | .01781 | .000 | -.1012 | -.0302 |
| 7 | 3 | .0405* | .01781 | .026 | .0049 | .0760 |
| | 5 | .0271 | .01781 | .132 | -.0084 | .0627 |
| | 9 | -.0229 | .01781 | .204 | -.0584 | .0127 |
| | 11 | -.0386* | .01781 | .034 | -.0741 | -.0030 |
| 9 | 3 | .0633* | .01781 | .001 | .0278 | .0989 |
| | 5 | .0500* | .01781 | .006 | .0145 | .0855 |
| | 7 | .0229 | .01781 | .204 | -.0127 | .0584 |
| | 11 | -.0157 | .01781 | .381 | -.0512 | .0198 |
| 11 | 3 | .0790* | .01781 | .000 | .0435 | .1146 |
| | 5 | .0657* | .01781 | .000 | .0302 | .1012 |
| | 7 | .0386* | .01781 | .034 | .0030 | .0741 |
| | 9 | .0157 | .01781 | .381 | -.0198 | .0512 |

Based on observed means.

The error term is Mean Square (Error) = .003.

*. The mean difference is significant at the .05 level.



E.2.3 Statistical analysis of viable cell counts (log CFU /mL) of pea protein paste and coconut milk fermentation for 24 hours

**Descriptives**

log CFU /mL

| Time (h) | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 0 | 3 | 5.4800 | .15000 | .08660 | 5.1074 | 5.8526 | 5.33 | 5.63 |
| 2 | 3 | 6.9600 | .18000 | .10392 | 6.5129 | 7.4071 | 6.78 | 7.14 |
| 4 | 3 | 7.7000 | .23000 | .13279 | 7.1286 | 8.2714 | 7.47 | 7.93 |
| 6 | 3 | 8.0800 | .17000 | .09815 | 7.6577 | 8.5023 | 7.91 | 8.25 |
| 8 | 3 | 8.6300 | .25000 | .14434 | 8.0090 | 9.2510 | 8.38 | 8.88 |
| 10 | 3 | 8.5400 | .26000 | .15011 | 7.8941 | 9.1859 | 8.28 | 8.80 |
| 12 | 3 | 8.4500 | .23000 | .13279 | 7.8786 | 9.0214 | 8.22 | 8.68 |
| 14 | 3 | 7.8933 | .33501 | .19342 | 7.0611 | 8.7256 | 7.56 | 8.23 |
| 16 | 3 | 7.3633 | .17502 | .10105 | 6.9286 | 7.7981 | 7.19 | 7.54 |
| 18 | 3 | 7.0700 | .12530 | .07234 | 6.7587 | 7.3813 | 6.94 | 7.19 |
| 20 | 3 | 6.9800 | .21000 | .12124 | 6.4583 | 7.5017 | 6.77 | 7.19 |
| 22 | 3 | 6.8333 | .21032 | .12143 | 6.3109 | 7.3558 | 6.63 | 7.05 |
| 24 | 3 | 6.7100 | .18682 | .10786 | 6.2459 | 7.1741 | 6.51 | 6.88 |
| Total | 39 | 7.4377 | .89106 | .14268 | 7.1488 | 7.7265 | 5.33 | 8.88 |

**Test of Homogeneity of Variances**

log CFU /mL

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .259 | 12 | 26 | .991 |

**ANOVA**

log CFU /mL

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 28.968 | 12 | 2.414 | 52.174 | .000 |
| Within Groups | 1.203 | 26 | .046 | | |
| Total | 30.171 | 38 | | | |

**Multiple Comparisons**

Dependent Variable: log CFU /mL

LSD

| (I) Time (h) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0 | 2 | -1.48000* | .17563 | .000 | -1.8410 | -1.1190 |
| | 4 | -2.22000* | .17563 | .000 | -2.5810 | -1.8590 |
| | 6 | -2.60000* | .17563 | .000 | -2.9610 | -2.2390 |
| | 8 | -3.15000* | .17563 | .000 | -3.5110 | -2.7890 |
| | 10 | -3.06000* | .17563 | .000 | -3.4210 | -2.6990 |
| | 12 | -2.97000* | .17563 | .000 | -3.3310 | -2.6090 |
| | 14 | -2.41333* | .17563 | .000 | -2.7743 | -2.0523 |
| | 16 | -1.88333* | .17563 | .000 | -2.2443 | -1.5223 |
| | 18 | -1.59000* | .17563 | .000 | -1.9510 | -1.2290 |
| | 20 | -1.50000* | .17563 | .000 | -1.8610 | -1.1390 |
| | 22 | -1.35333* | .17563 | .000 | -1.7143 | -.9923 |
| | 24 | -1.23000* | .17563 | .000 | -1.5910 | -.8690 |
| 2 | 0 | 1.48000* | .17563 | .000 | 1.1190 | 1.8410 |
| | 4 | -.74000* | .17563 | .000 | -1.1010 | -.3790 |
| | 6 | -1.12000* | .17563 | .000 | -1.4810 | -.7590 |
| | 8 | -1.67000* | .17563 | .000 | -2.0310 | -1.3090 |
| | 10 | -1.58000* | .17563 | .000 | -1.9410 | -1.2190 |
| | 12 | -1.49000* | .17563 | .000 | -1.8510 | -1.1290 |
| | 14 | -.93333* | .17563 | .000 | -1.2943 | -.5723 |
| | 16 | -.40333* | .17563 | .030 | -.7643 | -.0423 |
| | 18 | -.11000 | .17563 | .537 | -.4710 | .2510 |
| | 20 | -.02000 | .17563 | .910 | -.3810 | .3410 |
| | 22 | .12667 | .17563 | .477 | -.2343 | .4877 |
| | 24 | .25000 | .17563 | .166 | -.1110 | .6110 |
| 4 | 0 | 2.22000* | .17563 | .000 | 1.8590 | 2.5810 |
| | 2 | .74000* | .17563 | .000 | .3790 | 1.1010 |
| | 6 | -.38000* | .17563 | .040 | -.7410 | -.0190 |
| | 8 | -.93000* | .17563 | .000 | -1.2910 | -.5690 |
| | 10 | -.84000* | .17563 | .000 | -1.2010 | -.4790 |
| | 12 | -.75000* | .17563 | .000 | -1.1110 | -.3890 |
| | 14 | -.19333 | .17563 | .281 | -.5543 | .1677 |
| | 16 | .33667 | .17563 | .066 | -.0243 | .6977 |
| | 18 | .63000* | .17563 | .001 | .2690 | .9910 |
| | 20 | .72000* | .17563 | .000 | .3590 | 1.0810 |
| | 22 | .86667* | .17563 | .000 | .5057 | 1.2277 |
| | 24 | .99000* | .17563 | .000 | .6290 | 1.3510 |
| 6 | 0 | 2.60000* | .17563 | .000 | 2.2390 | 2.9610 |
| | 2 | 1.12000* | .17563 | .000 | .7590 | 1.4810 |
| | 4 | .38000* | .17563 | .040 | .0190 | .7410 |
| | 8 | -.55000* | .17563 | .004 | -.9110 | -.1890 |
| | 10 | -.46000* | .17563 | .015 | -.8210 | -.0990 |
| | 12 | -.37000* | .17563 | .045 | -.7310 | -.0090 |
| | 14 | .18667 | .17563 | .298 | -.1743 | .5477 |
| | 16 | .71667* | .17563 | .000 | .3557 | 1.0777 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 18 | 1.01000* | .17563 | .000 | .6490 | 1.3710 |
| | 20 | 1.10000* | .17563 | .000 | .7390 | 1.4610 |
| | 22 | 1.24667* | .17563 | .000 | .8857 | 1.6077 |
| | 24 | 1.37000* | .17563 | .000 | 1.0090 | 1.7310 |
| | 0 | 3.15000* | .17563 | .000 | 2.7890 | 3.5110 |
| | 2 | 1.67000* | .17563 | .000 | 1.3090 | 2.0310 |
| | 4 | .93000* | .17563 | .000 | .5690 | 1.2910 |
| | 6 | .55000* | .17563 | .004 | .1890 | .9110 |
| | 10 | .09000 | .17563 | .613 | -.2710 | .4510 |
| | 12 | .18000 | .17563 | .315 | -.1810 | .5410 |
| 8 | 14 | .73667* | .17563 | .000 | .3757 | 1.0977 |
| | 16 | 1.26667* | .17563 | .000 | .9057 | 1.6277 |
| | 18 | 1.56000* | .17563 | .000 | 1.1990 | 1.9210 |
| | 20 | 1.65000* | .17563 | .000 | 1.2890 | 2.0110 |
| | 22 | 1.79667* | .17563 | .000 | 1.4357 | 2.1577 |
| | 24 | 1.92000* | .17563 | .000 | 1.5590 | 2.2810 |
| | 0 | 3.06000* | .17563 | .000 | 2.6990 | 3.4210 |
| | 2 | 1.58000* | .17563 | .000 | 1.2190 | 1.9410 |
| | 4 | .84000* | .17563 | .000 | .4790 | 1.2010 |
| | 6 | .46000* | .17563 | .015 | .0990 | .8210 |
| | 8 | -.09000 | .17563 | .613 | -.4510 | .2710 |
| | 12 | .09000 | .17563 | .613 | -.2710 | .4510 |
| 10 | 14 | .64667* | .17563 | .001 | .2857 | 1.0077 |
| | 16 | 1.17667* | .17563 | .000 | .8157 | 1.5377 |
| | 18 | 1.47000* | .17563 | .000 | 1.1090 | 1.8310 |
| | 20 | 1.56000* | .17563 | .000 | 1.1990 | 1.9210 |
| | 22 | 1.70667* | .17563 | .000 | 1.3457 | 2.0677 |
| | 24 | 1.83000* | .17563 | .000 | 1.4690 | 2.1910 |
| | 0 | 2.97000* | .17563 | .000 | 2.6090 | 3.3310 |
| | 2 | 1.49000* | .17563 | .000 | 1.1290 | 1.8510 |
| | 4 | .75000* | .17563 | .000 | .3890 | 1.1110 |
| | 6 | .37000* | .17563 | .045 | .0090 | .7310 |
| | 8 | -.18000 | .17563 | .315 | -.5410 | .1810 |
| | 10 | -.09000 | .17563 | .613 | -.4510 | .2710 |
| 12 | 14 | .55667* | .17563 | .004 | .1957 | .9177 |
| | 16 | 1.08667* | .17563 | .000 | .7257 | 1.4477 |
| | 18 | 1.38000* | .17563 | .000 | 1.0190 | 1.7410 |
| | 20 | 1.47000* | .17563 | .000 | 1.1090 | 1.8310 |
| | 22 | 1.61667* | .17563 | .000 | 1.2557 | 1.9777 |
| | 24 | 1.74000* | .17563 | .000 | 1.3790 | 2.1010 |
| | 0 | 2.41333* | .17563 | .000 | 2.0523 | 2.7743 |
| | 2 | .93333* | .17563 | .000 | .5723 | 1.2943 |
| | 4 | .19333 | .17563 | .281 | -.1677 | .5543 |
| | 6 | -.18667 | .17563 | .298 | -.5477 | .1743 |
| 14 | 8 | -.73667* | .17563 | .000 | -1.0977 | -.3757 |
| | 10 | -.64667* | .17563 | .001 | -1.0077 | -.2857 |
| | 12 | -.55667* | .17563 | .004 | -.9177 | -.1957 |
| | 16 | .53000* | .17563 | .006 | .1690 | .8910 |
| | 18 | .82333* | .17563 | .000 | .4623 | 1.1843 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 20 | .91333* | .17563 | .000 | .5523 | 1.2743 |
| | 22 | 1.06000* | .17563 | .000 | .6990 | 1.4210 |
| | 24 | 1.18333* | .17563 | .000 | .8223 | 1.5443 |
| | 0 | 1.88333* | .17563 | .000 | 1.5223 | 2.2443 |
| | 2 | .40333* | .17563 | .030 | .0423 | .7643 |
| | 4 | -.33667 | .17563 | .066 | -.6977 | .0243 |
| | 6 | -.71667* | .17563 | .000 | -1.0777 | -.3557 |
| | 8 | -1.26667* | .17563 | .000 | -1.6277 | -.9057 |
| 16 | 10 | -1.17667* | .17563 | .000 | -1.5377 | -.8157 |
| | 12 | -1.08667* | .17563 | .000 | -1.4477 | -.7257 |
| | 14 | -.53000* | .17563 | .006 | -.8910 | -.1690 |
| | 18 | .29333 | .17563 | .107 | -.0677 | .6543 |
| | 20 | .38333* | .17563 | .038 | .0223 | .7443 |
| | 22 | .53000* | .17563 | .006 | .1690 | .8910 |
| | 24 | .65333* | .17563 | .001 | .2923 | 1.0143 |
| | 0 | 1.59000* | .17563 | .000 | 1.2290 | 1.9510 |
| | 2 | .11000 | .17563 | .537 | -.2510 | .4710 |
| | 4 | -.63000* | .17563 | .001 | -.9910 | -.2690 |
| | 6 | -1.01000* | .17563 | .000 | -1.3710 | -.6490 |
| | 8 | -1.56000* | .17563 | .000 | -1.9210 | -1.1990 |
| 18 | 10 | -1.47000* | .17563 | .000 | -1.8310 | -1.1090 |
| | 12 | -1.38000* | .17563 | .000 | -1.7410 | -1.0190 |
| | 14 | -.82333* | .17563 | .000 | -1.1843 | -.4623 |
| | 16 | -.29333 | .17563 | .107 | -.6543 | .0677 |
| | 20 | .09000 | .17563 | .613 | -.2710 | .4510 |
| | 22 | .23667 | .17563 | .189 | -.1243 | .5977 |
| | 24 | .36000 | .17563 | .051 | -.0010 | .7210 |
| | 0 | 1.50000* | .17563 | .000 | 1.1390 | 1.8610 |
| | 2 | .02000 | .17563 | .910 | -.3410 | .3810 |
| | 4 | -.72000* | .17563 | .000 | -1.0810 | -.3590 |
| | 6 | -1.10000* | .17563 | .000 | -1.4610 | -.7390 |
| | 8 | -1.65000* | .17563 | .000 | -2.0110 | -1.2890 |
| 20 | 10 | -1.56000* | .17563 | .000 | -1.9210 | -1.1990 |
| | 12 | -1.47000* | .17563 | .000 | -1.8310 | -1.1090 |
| | 14 | -.91333* | .17563 | .000 | -1.2743 | -.5523 |
| | 16 | -.38333* | .17563 | .038 | -.7443 | -.0223 |
| | 18 | -.09000 | .17563 | .613 | -.4510 | .2710 |
| | 22 | .14667 | .17563 | .411 | -.2143 | .5077 |
| | 24 | .27000 | .17563 | .136 | -.0910 | .6310 |
| | 0 | 1.35333* | .17563 | .000 | .9923 | 1.7143 |
| | 2 | -.12667 | .17563 | .477 | -.4877 | .2343 |
| | 4 | -.86667* | .17563 | .000 | -1.2277 | -.5057 |
| | 6 | -1.24667* | .17563 | .000 | -1.6077 | -.8857 |
| | 8 | -1.79667* | .17563 | .000 | -2.1577 | -1.4357 |
| 22 | 10 | -1.70667* | .17563 | .000 | -2.0677 | -1.3457 |
| | 12 | -1.61667* | .17563 | .000 | -1.9777 | -1.2557 |
| | 14 | -1.06000* | .17563 | .000 | -1.4210 | -.6990 |
| | 16 | -.53000* | .17563 | .006 | -.8910 | -.1690 |
| | 18 | -.23667 | .17563 | .189 | -.5977 | .1243 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 24 | 20 | -.14667 | .17563 | .411 | -.5077 | .2143 |
| | 24 | .12333 | .17563 | .489 | -.2377 | .4843 |
| | 0 | 1.23000* | .17563 | .000 | .8690 | 1.5910 |
| | 2 | -.25000 | .17563 | .166 | -.6110 | .1110 |
| | 4 | -.99000* | .17563 | .000 | -1.3510 | -.6290 |
| | 6 | -1.37000* | .17563 | .000 | -1.7310 | -1.0090 |
| | 8 | -1.92000* | .17563 | .000 | -2.2810 | -1.5590 |
| | 10 | -1.83000* | .17563 | .000 | -2.1910 | -1.4690 |
| | 12 | -1.74000* | .17563 | .000 | -2.1010 | -1.3790 |
| | 14 | -1.18333* | .17563 | .000 | -1.5443 | -.8223 |
| | 16 | -.65333* | .17563 | .001 | -1.0143 | -.2923 |
| | 18 | -.36000 | .17563 | .051 | -.7210 | .0010 |
| | 20 | -.27000 | .17563 | .136 | -.6310 | .0910 |
| | 22 | -.12333 | .17563 | .489 | -.4843 | .2377 |

*. The mean difference is significant at the 0.05 level.

## E.2.4 Statistical analysis of viable cell counts (log CFU /mL) for orthogonal test

**Descriptives**

Cell count /log CFU /mL

| Experimental number | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 1 | 3 | 8.7800 | .21000 | .12124 | 8.2583 | 9.3017 | 8.57 | 8.99 |
| 2 | 3 | 8.5400 | .32000 | .18475 | 7.7451 | 9.3349 | 8.22 | 8.86 |
| 3 | 3 | 8.4300 | .44000 | .25403 | 7.3370 | 9.5230 | 7.99 | 8.87 |
| 4 | 3 | 8.6500 | .33000 | .19053 | 7.8302 | 9.4698 | 8.32 | 8.98 |
| 5 | 3 | 8.1800 | .22000 | .12702 | 7.6335 | 8.7265 | 7.96 | 8.40 |
| 6 | 3 | 8.5200 | .15000 | .08660 | 8.1474 | 8.8926 | 8.37 | 8.67 |
| 7 | 3 | 8.5100 | .36000 | .20785 | 7.6157 | 9.4043 | 8.15 | 8.87 |
| 8 | 3 | 8.4100 | .20000 | .11547 | 7.9132 | 8.9068 | 8.21 | 8.61 |
| 9 | 3 | 8.0000 | .28000 | .16166 | 7.3044 | 8.6956 | 7.72 | 8.28 |
| Total | 27 | 8.4467 | .33191 | .06388 | 8.3154 | 8.5780 | 7.72 | 8.99 |

**Test of Homogeneity of Variances**

Cell count /log CFU /mL

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .398 | 8 | 18 | .907 |

**ANOVA**

Cell count /log CFU /mL

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.328 | 8 | .166 | 1.946 | .115 |
| Within Groups | 1.536 | 18 | .085 | | |
| Total | 2.864 | 26 | | | |

**Multiple Comparisons**

Dependent Variable: Cell count /log CFU /mL

LSD

| (I) Experimental number | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | .24000 | .23850 | .328 | -.2611 | .7411 |
| | 3 | .35000 | .23850 | .159 | -.1511 | .8511 |
| | 4 | .13000 | .23850 | .592 | -.3711 | .6311 |
| | 5 | .60000* | .23850 | .022 | .0989 | 1.1011 |
| | 6 | .26000 | .23850 | .290 | -.2411 | .7611 |
| | 7 | .27000 | .23850 | .272 | -.2311 | .7711 |
| | 8 | .37000 | .23850 | .138 | -.1311 | .8711 |
| | 9 | .78000* | .23850 | .004 | .2789 | 1.2811 |
| 2 | 1 | -.24000 | .23850 | .328 | -.7411 | .2611 |
| | 3 | .11000 | .23850 | .650 | -.3911 | .6111 |
| | 4 | -.11000 | .23850 | .650 | -.6111 | .3911 |
| | 5 | .36000 | .23850 | .149 | -.1411 | .8611 |
| | 6 | .02000 | .23850 | .934 | -.4811 | .5211 |
| | 7 | .03000 | .23850 | .901 | -.4711 | .5311 |
| | 8 | .13000 | .23850 | .592 | -.3711 | .6311 |
| | 9 | .54000* | .23850 | .036 | .0389 | 1.0411 |
| 3 | 1 | -.35000 | .23850 | .159 | -.8511 | .1511 |
| | 2 | -.11000 | .23850 | .650 | -.6111 | .3911 |
| | 4 | -.22000 | .23850 | .369 | -.7211 | .2811 |
| | 5 | .25000 | .23850 | .308 | -.2511 | .7511 |
| | 6 | -.09000 | .23850 | .710 | -.5911 | .4111 |
| | 7 | -.08000 | .23850 | .741 | -.5811 | .4211 |
| | 8 | .02000 | .23850 | .934 | -.4811 | .5211 |
| | 9 | .43000 | .23850 | .088 | -.0711 | .9311 |
| 4 | 1 | -.13000 | .23850 | .592 | -.6311 | .3711 |
| | 2 | .11000 | .23850 | .650 | -.3911 | .6111 |
| | 3 | .22000 | .23850 | .369 | -.2811 | .7211 |
| | 5 | .47000 | .23850 | .064 | -.0311 | .9711 |
| | 6 | .13000 | .23850 | .592 | -.3711 | .6311 |
| | 7 | .14000 | .23850 | .564 | -.3611 | .6411 |
| | 8 | .24000 | .23850 | .328 | -.2611 | .7411 |
| | 9 | .65000* | .23850 | .014 | .1489 | 1.1511 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 1 | -.60000* | .23850 | .022 | -1.1011 | -.0989 |
| | 2 | -.36000 | .23850 | .149 | -.8611 | .1411 |
| | 3 | -.25000 | .23850 | .308 | -.7511 | .2511 |
| | 4 | -.47000 | .23850 | .064 | -.9711 | .0311 |
| | 6 | -.34000 | .23850 | .171 | -.8411 | .1611 |
| | 7 | -.33000 | .23850 | .183 | -.8311 | .1711 |
| | 8 | -.23000 | .23850 | .348 | -.7311 | .2711 |
| | 9 | .18000 | .23850 | .460 | -.3211 | .6811 |
| 6 | 1 | -.26000 | .23850 | .290 | -.7611 | .2411 |
| | 2 | -.02000 | .23850 | .934 | -.5211 | .4811 |
| | 3 | .09000 | .23850 | .710 | -.4111 | .5911 |
| | 4 | -.13000 | .23850 | .592 | -.6311 | .3711 |
| | 5 | .34000 | .23850 | .171 | -.1611 | .8411 |
| | 7 | .01000 | .23850 | .967 | -.4911 | .5111 |
| | 8 | .11000 | .23850 | .650 | -.3911 | .6111 |
| | 9 | .52000* | .23850 | .043 | .0189 | 1.0211 |
| 7 | 1 | -.27000 | .23850 | .272 | -.7711 | .2311 |
| | 2 | -.03000 | .23850 | .901 | -.5311 | .4711 |
| | 3 | .08000 | .23850 | .741 | -.4211 | .5811 |
| | 4 | -.14000 | .23850 | .564 | -.6411 | .3611 |
| | 5 | .33000 | .23850 | .183 | -.1711 | .8311 |
| | 6 | -.01000 | .23850 | .967 | -.5111 | .4911 |
| | 8 | .10000 | .23850 | .680 | -.4011 | .6011 |
| | 9 | .51000* | .23850 | .046 | .0089 | 1.0111 |
| 8 | 1 | -.37000 | .23850 | .138 | -.8711 | .1311 |
| | 2 | -.13000 | .23850 | .592 | -.6311 | .3711 |
| | 3 | -.02000 | .23850 | .934 | -.5211 | .4811 |
| | 4 | -.24000 | .23850 | .328 | -.7411 | .2611 |
| | 5 | .23000 | .23850 | .348 | -.2711 | .7311 |
| | 6 | -.11000 | .23850 | .650 | -.6111 | .3911 |
| | 7 | -.10000 | .23850 | .680 | -.6011 | .4011 |
| | 9 | .41000 | .23850 | .103 | -.0911 | .9111 |
| 9 | 1 | -.78000* | .23850 | .004 | -1.2811 | -.2789 |
| | 2 | -.54000* | .23850 | .036 | -1.0411 | -.0389 |
| | 3 | -.43000 | .23850 | .088 | -.9311 | .0711 |
| | 4 | -.65000* | .23850 | .014 | -1.1511 | -.1489 |
| | 5 | -.18000 | .23850 | .460 | -.6811 | .3211 |
| | 6 | -.52000* | .23850 | .043 | -1.0211 | -.0189 |
| | 7 | -.51000* | .23850 | .046 | -1.0111 | -.0089 |
| | 8 | -.41000 | .23850 | .103 | -.9111 | .0911 |

*. The mean difference is significant at the 0.05 level.

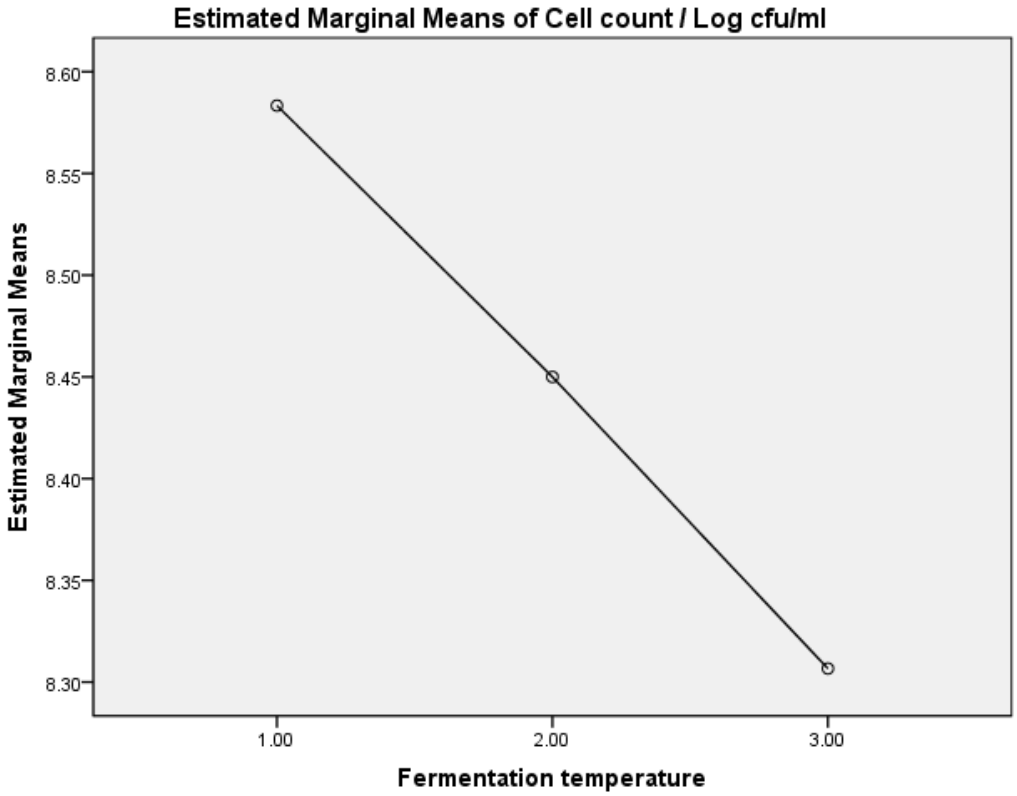
E.2.5 Statistical analysis of orthogonal test for bacteria growth

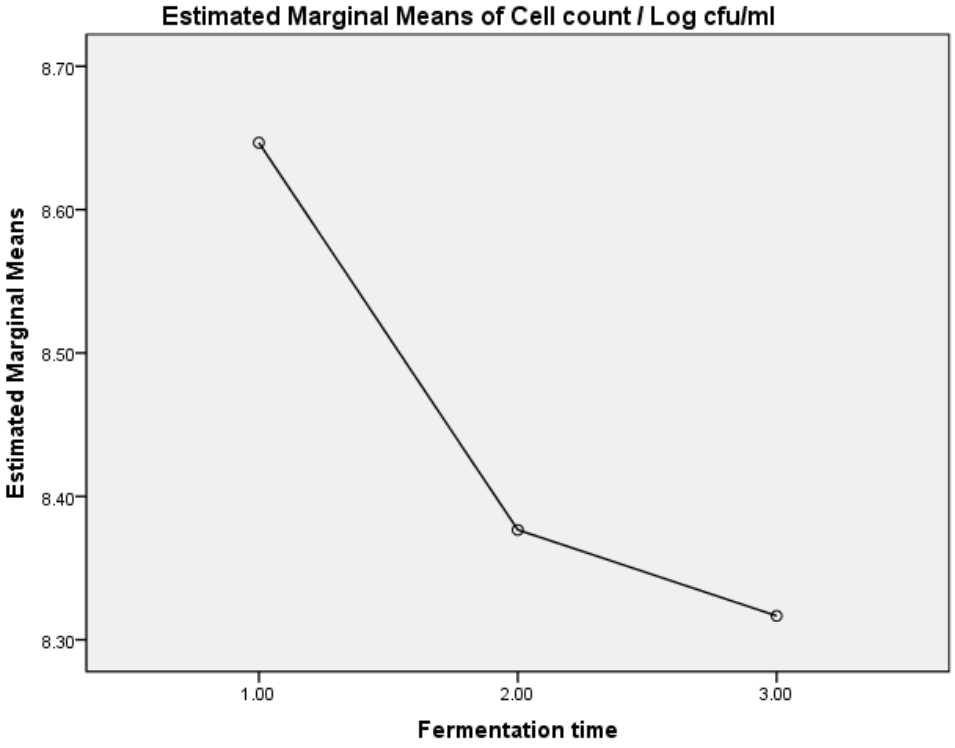
**Tests of Between-Subjects Effects**

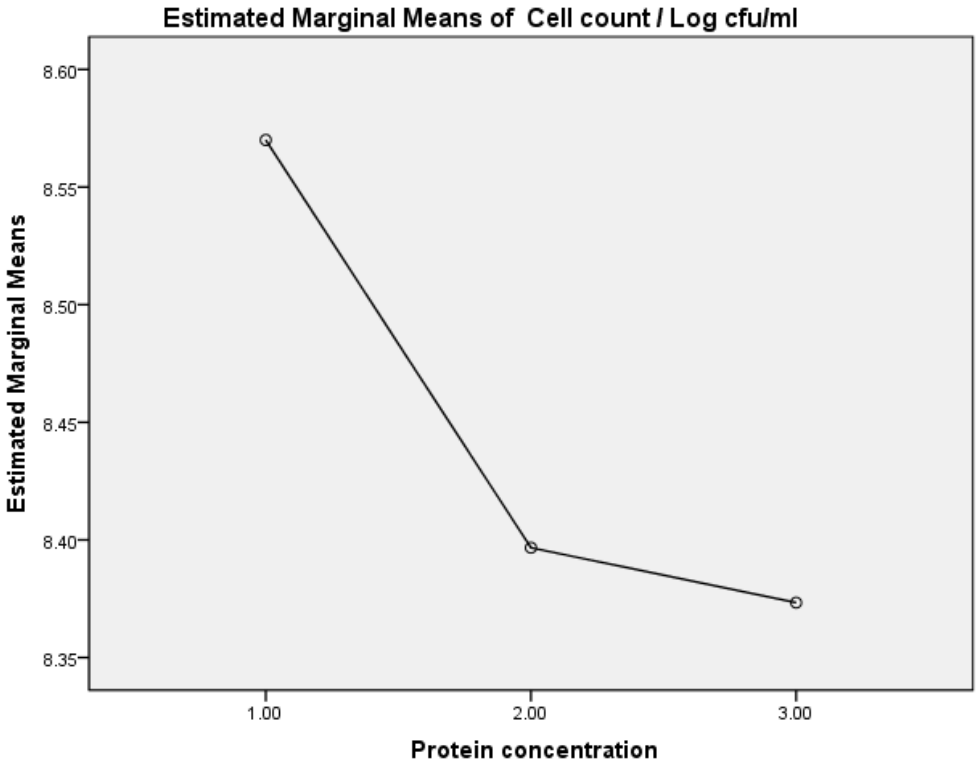
Dependent Variable: Visible cell counts /log CFU /mL

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | .370[a] | 6 | .062 | 1.681 | .419 |
| Intercept | 642.116 | 1 | 642.116 | 17528.178 | .000 |
| Fermentation temperature | .115 | 2 | .057 | 1.568 | .389 |
| Fermentation time | .185 | 2 | .093 | 2.530 | .283 |
| Protein concentration | .069 | 2 | .035 | .945 | .514 |
| Error | .073 | 2 | .037 | | |
| Total | 642.558 | 9 | | | |
| Corrected Total | .443 | 8 | | | |

a. R Squared = .835 (Adjusted R Squared = .338)




Estimated Marginal Means of Cell count / Log cfu/ml
Estimated Marginal Means
8.70
8.60
8.50
8.40
8.30
1.00
2.00
3.00
Fermentation time


Estimated Marginal Means of Cell count / Log cfu/ml
Estimated Marginal Means
8.60
8.55
8.50
8.45
8.40
8.35
1.00
2.00
3.00
Protein concentration

E.2.6 Statistical analysis of sensory evaluation of semi-trained sensory panel (n=18) of the orthogonal test

**Descriptives**

Average score of overall acceptability

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 1 | 3 | 6.5000 | .50000 | .28868 | 5.2579 | 7.7421 | 6.00 | 7.00 |
| 2 | 3 | 5.5000 | .50000 | .28868 | 4.2579 | 6.7421 | 5.00 | 6.00 |
| 3 | 3 | 4.6667 | .15275 | .08819 | 4.2872 | 5.0461 | 4.50 | 4.80 |
| 4 | 3 | 5.6667 | .15275 | .08819 | 5.2872 | 6.0461 | 5.50 | 5.80 |
| 5 | 3 | 4.0000 | 0.00000 | 0.00000 | 4.0000 | 4.0000 | 4.00 | 4.00 |
| 6 | 3 | 6.2000 | .50000 | .28868 | 4.9579 | 7.4421 | 5.70 | 6.70 |
| 7 | 3 | 6.1667 | .35119 | .20276 | 5.2943 | 7.0391 | 5.80 | 6.50 |
| 8 | 3 | 5.8333 | .35119 | .20276 | 4.9609 | 6.7057 | 5.50 | 6.20 |
| 9 | 3 | 4.5000 | .20000 | .11547 | 4.0032 | 4.9968 | 4.30 | 4.70 |
| Total | 27 | 5.4481 | .88028 | .16941 | 5.0999 | 5.7964 | 4.00 | 7.00 |

**Test of Homogeneity of Variances**

Average score of overall acceptability

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| 1.163 | 8 | 18 | .372 |

**ANOVA**

Average score of overall acceptability

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 17.981 | 8 | 2.248 | 18.672 | .000 |
| Within Groups | 2.167 | 18 | .120 | | |
| Total | 20.147 | 26 | | | |

**Multiple Comparisons**

Dependent Variable: Average score of overall acceptability

LSD

| (I) Experimental number | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | 1.00000* | .28328 | .002 | .4049 | 1.5951 |
| | 3 | 1.83333* | .28328 | .000 | 1.2382 | 2.4285 |
| | 4 | .83333* | .28328 | .009 | .2382 | 1.4285 |
| | 5 | 2.50000* | .28328 | .000 | 1.9049 | 3.0951 |
| | 6 | .30000 | .28328 | .304 | -.2951 | .8951 |
| | 7 | .33333 | .28328 | .255 | -.2618 | .9285 |
| | 8 | .66667* | .28328 | .030 | .0715 | 1.2618 |
| | 9 | 2.00000* | .28328 | .000 | 1.4049 | 2.5951 |
| 2 | 1 | -1.00000* | .28328 | .002 | -1.5951 | -.4049 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3 | .83333* | .28328 | .009 | .2382 | 1.4285 |
| | 4 | -.16667 | .28328 | .564 | -.7618 | .4285 |
| | 5 | 1.50000* | .28328 | .000 | .9049 | 2.0951 |
| | 6 | -.70000* | .28328 | .024 | -1.2951 | -.1049 |
| | 7 | -.66667* | .28328 | .030 | -1.2618 | -.0715 |
| | 8 | -.33333 | .28328 | .255 | -.9285 | .2618 |
| | 9 | 1.00000* | .28328 | .002 | .4049 | 1.5951 |
| | 1 | -1.83333* | .28328 | .000 | -2.4285 | -1.2382 |
| | 2 | -.83333* | .28328 | .009 | -1.4285 | -.2382 |
| | 4 | -1.00000* | .28328 | .002 | -1.5951 | -.4049 |
| 3 | 5 | .66667* | .28328 | .030 | .0715 | 1.2618 |
| | 6 | -1.53333* | .28328 | .000 | -2.1285 | -.9382 |
| | 7 | -1.50000* | .28328 | .000 | -2.0951 | -.9049 |
| | 8 | -1.16667* | .28328 | .001 | -1.7618 | -.5715 |
| | 9 | .16667 | .28328 | .564 | -.4285 | .7618 |
| | 1 | -.83333* | .28328 | .009 | -1.4285 | -.2382 |
| | 2 | .16667 | .28328 | .564 | -.4285 | .7618 |
| | 3 | 1.00000* | .28328 | .002 | .4049 | 1.5951 |
| | 5 | 1.66667* | .28328 | .000 | 1.0715 | 2.2618 |
| 4 | 6 | -.53333 | .28328 | .076 | -1.1285 | .0618 |
| | 7 | -.50000 | .28328 | .095 | -1.0951 | .0951 |
| | 8 | -.16667 | .28328 | .564 | -.7618 | .4285 |
| | 9 | 1.16667* | .28328 | .001 | .5715 | 1.7618 |
| | 1 | -2.50000* | .28328 | .000 | -3.0951 | -1.9049 |
| | 2 | -1.50000* | .28328 | .000 | -2.0951 | -.9049 |
| | 3 | -.66667* | .28328 | .030 | -1.2618 | -.0715 |
| | 4 | -1.66667* | .28328 | .000 | -2.2618 | -1.0715 |
| 5 | 6 | -2.20000* | .28328 | .000 | -2.7951 | -1.6049 |
| | 7 | -2.16667* | .28328 | .000 | -2.7618 | -1.5715 |
| | 8 | -1.83333* | .28328 | .000 | -2.4285 | -1.2382 |
| | 9 | -.50000 | .28328 | .095 | -1.0951 | .0951 |
| | 1 | -.30000 | .28328 | .304 | -.8951 | .2951 |
| | 2 | .70000* | .28328 | .024 | .1049 | 1.2951 |
| | 3 | 1.53333* | .28328 | .000 | .9382 | 2.1285 |
| | 4 | .53333 | .28328 | .076 | -.0618 | 1.1285 |
| 6 | 5 | 2.20000* | .28328 | .000 | 1.6049 | 2.7951 |
| | 7 | .03333 | .28328 | .908 | -.5618 | .6285 |
| | 8 | .36667 | .28328 | .212 | -.2285 | .9618 |
| | 9 | 1.70000* | .28328 | .000 | 1.1049 | 2.2951 |
| | 1 | -.33333 | .28328 | .255 | -.9285 | .2618 |
| | 2 | .66667* | .28328 | .030 | .0715 | 1.2618 |
| | 3 | 1.50000* | .28328 | .000 | .9049 | 2.0951 |
| | 4 | .50000 | .28328 | .095 | -.0951 | 1.0951 |
| 7 | 5 | 2.16667* | .28328 | .000 | 1.5715 | 2.7618 |
| | 6 | -.03333 | .28328 | .908 | -.6285 | .5618 |
| | 8 | .33333 | .28328 | .255 | -.2618 | .9285 |
| | 9 | 1.66667* | .28328 | .000 | 1.0715 | 2.2618 |
| | 1 | -.66667* | .28328 | .030 | -1.2618 | -.0715 |
| 8 | 2 | .33333 | .28328 | .255 | -.2618 | .9285 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 1.16667* | .28328 | .001 | .5715 | 1.7618 |
| | 4 | .16667 | .28328 | .564 | -.4285 | .7618 |
| | 5 | 1.83333* | .28328 | .000 | 1.2382 | 2.4285 |
| | 6 | -.36667 | .28328 | .212 | -.9618 | .2285 |
| | 7 | -.33333 | .28328 | .255 | -.9285 | .2618 |
| | 9 | 1.33333* | .28328 | .000 | .7382 | 1.9285 |
| | 1 | -2.00000* | .28328 | .000 | -2.5951 | -1.4049 |
| | 2 | -1.00000* | .28328 | .002 | -1.5951 | -.4049 |
| | 3 | -.16667 | .28328 | .564 | -.7618 | .4285 |
| | 4 | -1.16667* | .28328 | .001 | -1.7618 | -.5715 |
| 9 | 5 | .50000 | .28328 | .095 | -.0951 | 1.0951 |
| | 6 | -1.70000* | .28328 | .000 | -2.2951 | -1.1049 |
| | 7 | -1.66667* | .28328 | .000 | -2.2618 | -1.0715 |
| | 8 | -1.33333* | .28328 | .000 | -1.9285 | -.7382 |

*. The mean difference is significant at the 0.05 level.

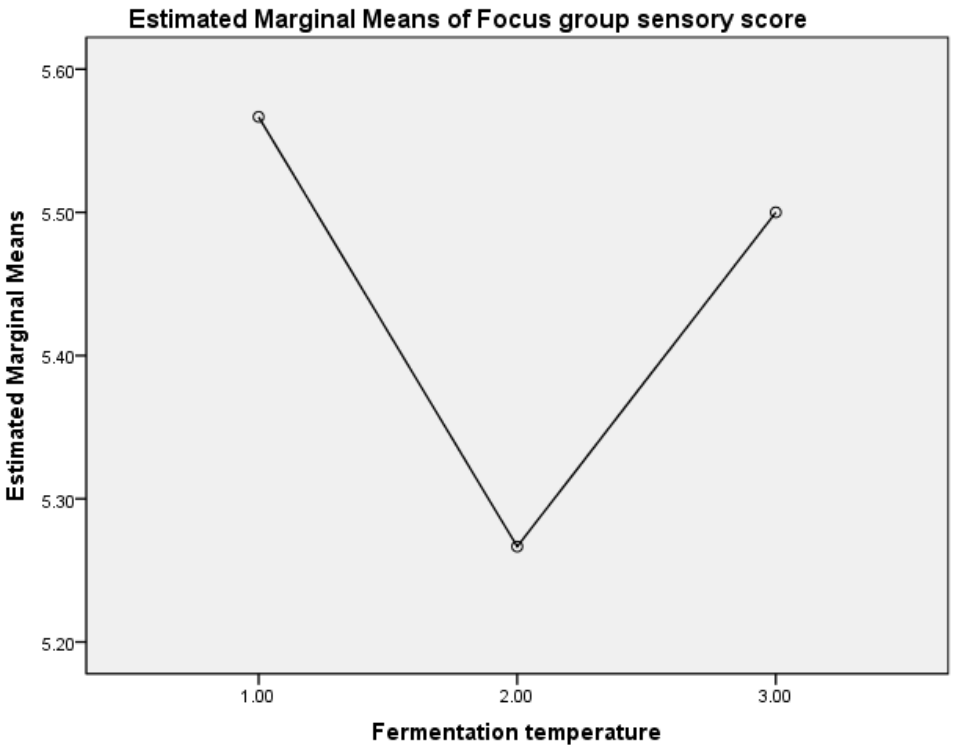
E.2.7 Statistical analysis of orthogonal test for semi-trained sensory panel (n=18) sensory evaluation

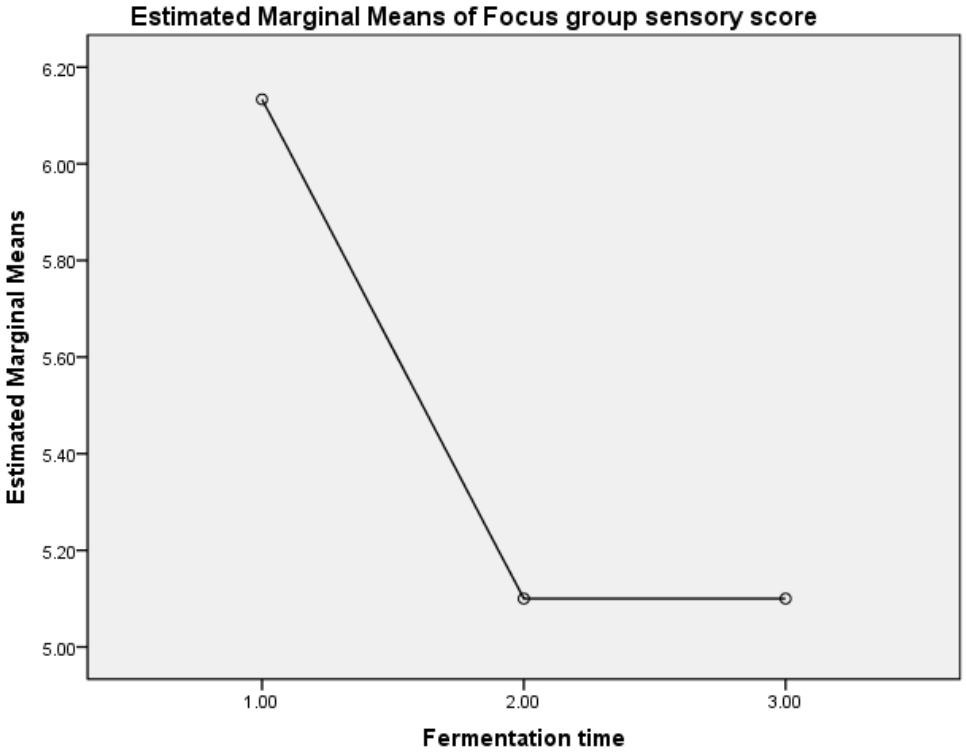
**Tests of Between-Subjects Effects**

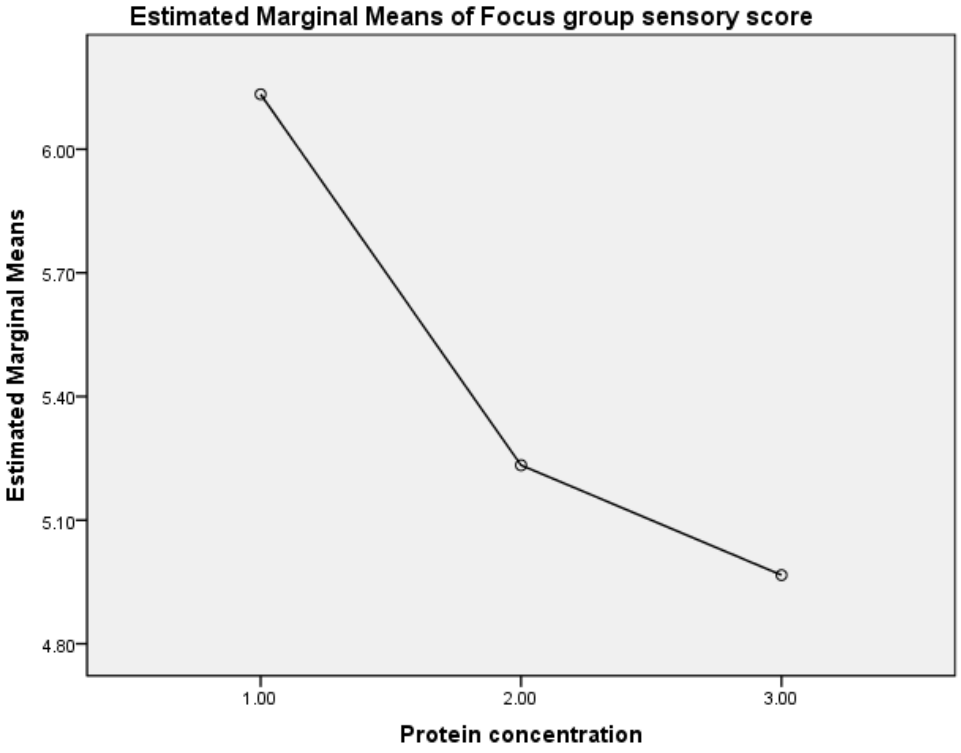
Dependent Variable: Semi-trained sensory panel sensory score

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 4.527[a] | 6 | .754 | 1.147 | .535 |
| Intercept | 266.778 | 1 | 266.778 | 405.574 | .002 |
| Fermentation temperature | .149 | 2 | .074 | .113 | .898 |
| Fermentation time | 2.136 | 2 | 1.068 | 1.623 | .381 |
| Protein concentration | 2.242 | 2 | 1.121 | 1.704 | .370 |
| Error | 1.316 | 2 | .658 | | |
| Total | 272.620 | 9 | | | |
| Corrected Total | 5.842 | 8 | | | |

a. R Squared = .775 (Adjusted R Squared = .099)


Estimated Marginal Means of Focus group sensory score
Estimated Marginal Means
5.60
5.50
5.40
5.30
5.20
1.00
2.00
3.00
Fermentation temperature


Estimated Marginal Means of Focus group sensory score
Estimated Marginal Means
6.20
6.00
5.80
5.60
5.40
5.20
5.00
1.00
2.00
3.00
Fermentation time




E.2.8 Statistical analysis of consumer sensory evaluation (n=90) of final fermented pea protein-coconut milk beverage

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| Appearance | 1 | 90 | 6.6667 | 1.09133 | .11504 | 6.4381 | 6.8952 | 5.00 | 8.00 |
| | 6 | 90 | 6.3667 | 1.14607 | .12081 | 6.1266 | 6.6067 | 4.00 | 8.00 |
| | 7 | 90 | 6.4000 | 1.17846 | .12422 | 6.1532 | 6.6468 | 4.00 | 8.00 |
| | Total | 270 | 6.4778 | 1.14289 | .06955 | 6.3408 | 6.6147 | 4.00 | 8.00 |
| Aroma | 1 | 90 | 6.7000 | 1.13623 | .11977 | 6.4620 | 6.9380 | 4.00 | 8.00 |
| | 6 | 90 | 6.6000 | 1.23434 | .13011 | 6.3415 | 6.8585 | 5.00 | 9.00 |
| | 7 | 90 | 6.4000 | 1.14950 | .12117 | 6.1592 | 6.6408 | 5.00 | 8.00 |
| | Total | 270 | 6.5667 | 1.17644 | .07160 | 6.4257 | 6.7076 | 4.00 | 9.00 |
| Sourness | 1 | 90 | 5.7000 | 1.25823 | .13263 | 5.4365 | 5.9635 | 2.00 | 8.00 |
| | 6 | 90 | 4.7333 | 1.67466 | .17652 | 4.3826 | 5.0841 | 2.00 | 8.00 |
| | 7 | 90 | 5.1000 | 1.35787 | .14313 | 4.8156 | 5.3844 | 3.00 | 8.00 |
| | Total | 270 | 5.1778 | 1.49032 | .09070 | 4.9992 | 5.3563 | 2.00 | 8.00 |
| Sweetness | 1 | 90 | 5.3222 | 1.47509 | .15549 | 5.0133 | 5.6312 | 2.00 | 8.00 |
| | 6 | 90 | 5.2000 | 1.58788 | .16738 | 4.8674 | 5.5326 | 2.00 | 9.00 |
| | 7 | 90 | 5.5000 | 1.15389 | .12163 | 5.2583 | 5.7417 | 3.00 | 8.00 |
| | Total | 270 | 5.3407 | 1.41769 | .08628 | 5.1709 | 5.5106 | 2.00 | 9.00 |
| Flavour | 1 | 90 | 5.7667 | 1.41461 | .14911 | 5.4704 | 6.0630 | 2.00 | 8.00 |
| | 6 | 90 | 5.3000 | 1.80168 | .18991 | 4.9226 | 5.6774 | 1.00 | 9.00 |
| | 7 | 90 | 5.3333 | 1.62840 | .17165 | 4.9923 | 5.6744 | 2.00 | 8.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | 270 | 5.4667 | 1.63056 | .09923 | 5.2713 | 5.6620 | 1.00 | 9.00 |
| Mouth feel | 1 | 90 | 6.1000 | 1.26358 | .13319 | 5.8353 | 6.3647 | 3.00 | 9.00 |
| | 6 | 90 | 5.5000 | 1.83137 | .19304 | 5.1164 | 5.8836 | 2.00 | 9.00 |
| | 7 | 90 | 5.1333 | 1.77498 | .18710 | 4.7616 | 5.5051 | 1.00 | 9.00 |
| | Total | 270 | 5.5778 | 1.68513 | .10255 | 5.3759 | 5.7797 | 1.00 | 9.00 |
| After taste | 1 | 90 | 5.9667 | 1.47983 | .15599 | 5.6567 | 6.2766 | 2.00 | 9.00 |
| | 6 | 90 | 5.4667 | 1.43941 | .15173 | 5.1652 | 5.7681 | 2.00 | 9.00 |
| | 7 | 90 | 5.3000 | 1.44914 | .15275 | 4.9965 | 5.6035 | 2.00 | 8.00 |
| | Total | 270 | 5.5778 | 1.47830 | .08997 | 5.4006 | 5.7549 | 2.00 | 9.00 |
| Overall acceptability | 1 | 90 | 6.2000 | 1.41580 | .14924 | 5.9035 | 6.4965 | 2.00 | 8.00 |
| | 6 | 90 | 5.4833 | 1.74570 | .18401 | 5.1177 | 5.8490 | 2.00 | 9.00 |
| | 7 | 90 | 5.4667 | 1.36736 | .14413 | 5.1803 | 5.7531 | 2.00 | 8.00 |
| | Total | 270 | 5.7167 | 1.55156 | .09443 | 5.5308 | 5.9026 | 2.00 | 9.00 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Appearance | Between Groups | 4.867 | 2 | 2.433 | 1.875 | .155 |
| | Within Groups | 346.500 | 267 | 1.298 | | |
| | Total | 351.367 | 269 | | | |
| Aroma | Between Groups | 4.200 | 2 | 2.100 | 1.523 | .220 |
| | Within Groups | 368.100 | 267 | 1.379 | | |
| | Total | 372.300 | 269 | | | |
| Sourness | Between Groups | 42.867 | 2 | 21.433 | 10.319 | .000 |
| | Within Groups | 554.600 | 267 | 2.077 | | |
| | Total | 597.467 | 269 | | | |
| Sweetness | Between Groups | 4.096 | 2 | 2.048 | 1.019 | .362 |
| | Within Groups | 536.556 | 267 | 2.010 | | |
| | Total | 540.652 | 269 | | | |
| Flavour | Between Groups | 12.200 | 2 | 6.100 | 2.317 | .101 |
| | Within Groups | 703.000 | 267 | 2.633 | | |
| | Total | 715.200 | 269 | | | |
| Mouth feel | Between Groups | 42.867 | 2 | 21.433 | 7.937 | .000 |
| | Within Groups | 721.000 | 267 | 2.700 | | |
| | Total | 763.867 | 269 | | | |
| After taste | Between Groups | 21.667 | 2 | 10.833 | 5.109 | .007 |
| | Within Groups | 566.200 | 267 | 2.121 | | |
| | Total | 587.867 | 269 | | | |
| Overall acceptability | Between Groups | 31.550 | 2 | 15.775 | 6.837 | .001 |
| | Within Groups | 616.025 | 267 | 2.307 | | |
| | Total | 647.575 | 269 | | | |

**Multiple Comparisons**

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Appearance | .308 | 2 | 267 | .735 |
| Aroma | 1.502 | 2 | 267 | .224 |
| Sourness | 8.349 | 2 | 267 | .000 |
| Sweetness | 2.536 | 2 | 267 | .081 |
| Flavour | 3.971 | 2 | 267 | .020 |
| Mouth feel | 10.171 | 2 | 267 | .000 |
| After taste | .065 | 2 | 267 | .937 |
| Overall acceptability | 2.826 | 2 | 267 | .061 |

LSD

| Dependent Variable: Sample number | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Appearance | 1 | 6 | .30000 | .16982 | .078 | -.0344 | .6344 |
| | | 7 | .26667 | .16982 | .118 | -.0677 | .6010 |
| | 6 | 1 | -.30000 | .16982 | .078 | -.6344 | .0344 |
| | | 7 | -.03333 | .16982 | .845 | -.3677 | .3010 |
| | 7 | 1 | -.26667 | .16982 | .118 | -.6010 | .0677 |
| | | 6 | .03333 | .16982 | .845 | -.3010 | .3677 |
| Aroma | 1 | 6 | .10000 | .17503 | .568 | -.2446 | .4446 |
| | | 7 | .30000 | .17503 | .088 | -.0446 | .6446 |
| | 6 | 1 | -.10000 | .17503 | .568 | -.4446 | .2446 |
| | | 7 | .20000 | .17503 | .254 | -.1446 | .5446 |
| | 7 | 1 | -.30000 | .17503 | .088 | -.6446 | .0446 |
| | | 6 | -.20000 | .17503 | .254 | -.5446 | .1446 |
| Sourness | 1 | 6 | .96667* | .21485 | .000 | .5437 | 1.3897 |
| | | 7 | .60000* | .21485 | .006 | .1770 | 1.0230 |
| | 6 | 1 | -.96667* | .21485 | .000 | -1.3897 | -.5437 |
| | | 7 | -.36667 | .21485 | .089 | -.7897 | .0563 |
| | 7 | 1 | -.60000* | .21485 | .006 | -1.0230 | -.1770 |
| | | 6 | .36667 | .21485 | .089 | -.0563 | .7897 |
| Sweetness | 1 | 6 | .12222 | .21132 | .564 | -.2938 | .5383 |
| | | 7 | -.17778 | .21132 | .401 | -.5938 | .2383 |
| | 6 | 1 | -.12222 | .21132 | .564 | -.5383 | .2938 |
| | | 7 | -.30000 | .21132 | .157 | -.7161 | .1161 |
| | 7 | 1 | .17778 | .21132 | .401 | -.2383 | .5938 |
| | | 6 | .30000 | .21132 | .157 | -.1161 | .7161 |
| Flavour | 1 | 6 | .46667 | .24189 | .055 | -.0096 | .9429 |
| | | 7 | .43333 | .24189 | .074 | -.0429 | .9096 |
| | 6 | 1 | -.46667 | .24189 | .055 | -.9429 | .0096 |
| | | 7 | -.03333 | .24189 | .890 | -.5096 | .4429 |
| | 7 | 1 | -.43333 | .24189 | .074 | -.9096 | .0429 |
| | | 6 | .03333 | .24189 | .890 | -.4429 | .5096 |
| Mouth feel | 1 | 6 | .60000* | .24497 | .015 | .1177 | 1.0823 |
| | | 7 | .96667* | .24497 | .000 | .4844 | 1.4490 |
| | 6 | 1 | -.60000* | .24497 | .015 | -1.0823 | -.1177 |
| | | 7 | .36667 | .24497 | .136 | -.1156 | .8490 |
| | 7 | 1 | -.96667* | .24497 | .000 | -1.4490 | -.4844 |
| | | 6 | -.36667 | .24497 | .136 | -.8490 | .1156 |
| After taste | 1 | 6 | .50000* | .21708 | .022 | .0726 | .9274 |
| | | 7 | .66667* | .21708 | .002 | .2393 | 1.0941 |
| | 6 | 1 | -.50000* | .21708 | .022 | -.9274 | -.0726 |
| | | 7 | .16667 | .21708 | .443 | -.2607 | .5941 |
| | 7 | 1 | -.66667* | .21708 | .002 | -1.0941 | -.2393 |
| | | 6 | -.16667 | .21708 | .443 | -.5941 | .2607 |
| Overall acceptability | 1 | 6 | .71667* | .22643 | .002 | .2708 | 1.1625 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 7 | .73333* | .22643 | .001 | .2875 | 1.1792 |
| | 6 | 1 | -.71667* | .22643 | .002 | -1.1625 | -.2708 |
| | | 7 | .01667 | .22643 | .941 | -.4292 | .4625 |
| | 7 | 1 | -.73333* | .22643 | .001 | -1.1792 | -.2875 |
| | | 6 | -.01667 | .22643 | .941 | -.4625 | .4292 |

*. The mean difference is significant at the 0.05 level.

## E.2.9 Statistical analysis of pH of fermented pea protein-coconut milk beverage during the fermentation

**Descriptives**

pH

| Time (h) | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 0 | 3 | 6.1533 | .12741 | .07356 | 5.8368 | 6.4698 | 6.07 | 6.30 |
| 2 | 3 | 5.9867 | .06028 | .03480 | 5.8369 | 6.1364 | 5.93 | 6.05 |
| 4 | 3 | 5.1367 | .09452 | .05457 | 4.9019 | 5.3715 | 5.03 | 5.21 |
| 6 | 3 | 4.5400 | .04583 | .02646 | 4.4262 | 4.6538 | 4.50 | 4.59 |
| 8 | 3 | 4.2900 | .01732 | .01000 | 4.2470 | 4.3330 | 4.28 | 4.31 |
| Total | 15 | 5.2213 | .77652 | .20050 | 4.7913 | 5.6514 | 4.28 | 6.30 |

**Multiple Comparisons**

Dependent Variable: pH

LSD

| (I) Time (h) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0 | 2 | .16667* | .06450 | .027 | .0230 | .3104 |
| | 4 | 1.01667* | .06450 | .000 | .8730 | 1.1604 |
| | 6 | 1.61333* | .06450 | .000 | 1.4696 | 1.7570 |
| | 8 | 1.86333* | .06450 | .000 | 1.7196 | 2.0070 |
| 2 | 0 | -.16667* | .06450 | .027 | -.3104 | -.0230 |
| | 4 | .85000* | .06450 | .000 | .7063 | .9937 |
| | 6 | 1.44667* | .06450 | .000 | 1.3030 | 1.5904 |
| | 8 | 1.69667* | .06450 | .000 | 1.5530 | 1.8404 |
| 4 | 0 | -1.01667* | .06450 | .000 | -1.1604 | -.8730 |
| | 2 | -.85000* | .06450 | .000 | -.9937 | -.7063 |
| | 6 | .59667* | .06450 | .000 | .4530 | .7404 |
| | 8 | .84667* | .06450 | .000 | .7030 | .9904 |
| 6 | 0 | -1.61333* | .06450 | .000 | -1.7570 | -1.4696 |
| | 2 | -1.44667* | .06450 | .000 | -1.5904 | -1.3030 |
| | 4 | -.59667* | .06450 | .000 | -.7404 | -.4530 |
| | 8 | .25000* | .06450 | .003 | .1063 | .3937 |
| 8 | 0 | -1.86333* | .06450 | .000 | -2.0070 | -1.7196 |
| | 2 | -1.69667* | .06450 | .000 | -1.8404 | -1.5530 |
| | 4 | -.84667* | .06450 | .000 | -.9904 | -.7030 |
| | 6 | -.25000* | .06450 | .003 | -.3937 | -.1063 |

*. The mean difference is significant at the 0.05 level.

**Test of Homogeneity of Variances**

pH

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| 3.535 | 4 | 10 | .048 |

**ANOVA**

pH

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 8.379 | 4 | 2.095 | 335.712 | .000 |
| Within Groups | .062 | 10 | .006 | | |
| Total | 8.442 | 14 | | | |

## E.2.10 Statistical analysis of titratable acid of fermented pea protein-coconut milk beverage during the fermentation

**Descriptives**

T.A. (%)

| Time (h) | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 0 | 3 | .0933 | .00577 | .00333 | .0790 | .1077 | .09 | .10 |
| 2 | 3 | .1200 | .01000 | .00577 | .0952 | .1448 | .11 | .13 |
| 4 | 3 | .2467 | .02517 | .01453 | .1842 | .3092 | .22 | .27 |
| 6 | 3 | .3367 | .02517 | .01453 | .2742 | .3992 | .31 | .36 |
| 8 | 3 | .5167 | .02517 | .01453 | .4542 | .5792 | .49 | .54 |
| Total | 15 | .2627 | .16078 | .04151 | .1736 | .3517 | .09 | .54 |

**Test of Homogeneity of Variances**

T.A. (%)

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| 1.324 | 4 | 10 | .326 |

**ANOVA**

T.A. (%)

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | .358 | 4 | .089 | 219.975 | .000 |
| Within Groups | .004 | 10 | .000 | | |
| Total | .362 | 14 | | | |

**Multiple Comparisons**

Dependent Variable: T.A. (%)

LSD

| (I) Time (h) | (J) Time (h) | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0 | 2 | -.02667 | .01647 | .136 | -.0634 | .0100 |
| | 4 | -.15333* | .01647 | .000 | -.1900 | -.1166 |
| | 6 | -.24333* | .01647 | .000 | -.2800 | -.2066 |
| | 8 | -.42333* | .01647 | .000 | -.4600 | -.3866 |
| 2 | 0 | .02667 | .01647 | .136 | -.0100 | .0634 |
| | 4 | -.12667* | .01647 | .000 | -.1634 | -.0900 |
| | 6 | -.21667* | .01647 | .000 | -.2534 | -.1800 |
| | 8 | -.39667* | .01647 | .000 | -.4334 | -.3600 |
| 4 | 0 | .15333* | .01647 | .000 | .1166 | .1900 |
| | 2 | .12667* | .01647 | .000 | .0900 | .1634 |
| | 6 | -.09000* | .01647 | .000 | -.1267 | -.0533 |
| | 8 | -.27000* | .01647 | .000 | -.3067 | -.2333 |
| 6 | 0 | .24333* | .01647 | .000 | .2066 | .2800 |
| | 2 | .21667* | .01647 | .000 | .1800 | .2534 |
| | 4 | .09000* | .01647 | .000 | .0533 | .1267 |
| | 8 | -.18000* | .01647 | .000 | -.2167 | -.1433 |
| 8 | 0 | .42333* | .01647 | .000 | .3866 | .4600 |
| | 2 | .39667* | .01647 | .000 | .3600 | .4334 |
| | 4 | .27000* | .01647 | .000 | .2333 | .3067 |
| | 6 | .18000* | .01647 | .000 | .1433 | .2167 |

*. The mean difference is significant at the 0.05 level.

## E.2.11 Statistical analysis of VCCs (log CFU /mL) of fermented pea protein-coconut milk beverage during the fermentation

**Descriptives**

Bacterial quantity (log CFU /mL)

| Time (h) | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 0 | 3 | 5.5400 | .10000 | .05774 | 5.2916 | 5.7884 | 5.44 | 5.64 |
| 2 | 3 | 6.9900 | .28000 | .16166 | 6.2944 | 7.6856 | 6.71 | 7.27 |
| 4 | 3 | 7.8500 | .30000 | .17321 | 7.1048 | 8.5952 | 7.55 | 8.15 |
| 6 | 3 | 8.1800 | .34000 | .19630 | 7.3354 | 9.0246 | 7.84 | 8.52 |
| 8 | 3 | 8.6100 | .35000 | .20207 | 7.7406 | 9.4794 | 8.26 | 8.96 |
| Total | 15 | 7.4340 | 1.15027 | .29700 | 6.7970 | 8.0710 | 5.44 | 8.96 |

**Test of Homogeneity of Variances**

Bacterial quantity (log CFU /mL)

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .494 | 4 | 10 | .741 |

**ANOVA**

Bacterial quantity (log CFU /mL)

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 17.691 | 4 | 4.423 | 53.094 | .000 |
| Within Groups | .833 | 10 | .083 | | |
| Total | 18.524 | 14 | | | |

**Multiple Comparisons**

Dependent Variable: Bacterial quantity (log CFU /mL)

LSD

| (I) Time (h) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0 | 2 | -1.45000* | .23566 | .000 | -1.9751 | -.9249 |
| | 4 | -2.31000* | .23566 | .000 | -2.8351 | -1.7849 |
| | 6 | -2.64000* | .23566 | .000 | -3.1651 | -2.1149 |
| | 8 | -3.07000* | .23566 | .000 | -3.5951 | -2.5449 |
| 2 | 0 | 1.45000* | .23566 | .000 | .9249 | 1.9751 |
| | 4 | -.86000* | .23566 | .004 | -1.3851 | -.3349 |
| | 6 | -1.19000* | .23566 | .000 | -1.7151 | -.6649 |
| | 8 | -1.62000* | .23566 | .000 | -2.1451 | -1.0949 |
| 4 | 0 | 2.31000* | .23566 | .000 | 1.7849 | 2.8351 |
| | 2 | .86000* | .23566 | .004 | .3349 | 1.3851 |
| | 6 | -.33000 | .23566 | .192 | -.8551 | .1951 |
| | 8 | -.76000* | .23566 | .009 | -1.2851 | -.2349 |
| 6 | 0 | 2.64000* | .23566 | .000 | 2.1149 | 3.1651 |
| | 2 | 1.19000* | .23566 | .000 | .6649 | 1.7151 |
| | 4 | .33000 | .23566 | .192 | -.1951 | .8551 |
| | 8 | -.43000 | .23566 | .098 | -.9551 | .0951 |
| 8 | 0 | 3.07000* | .23566 | .000 | 2.5449 | 3.5951 |
| | 2 | 1.62000* | .23566 | .000 | 1.0949 | 2.1451 |
| | 4 | .76000* | .23566 | .009 | .2349 | 1.2851 |
| | 6 | .43000 | .23566 | .098 | -.0951 | .9551 |

*. The mean difference is significant at the 0.05 level.

E.2.12 Statistical analysis of colour of fermented pea protein-coconut milk beverage during the fermentation

**Descriptives**

| | Time (h) | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| L* | 0 | 3 | 73.3967 | .27154 | .15677 | 72.7221 | 74.0712 | 73.23 | 73.71 |
| | 2 | 3 | 73.5967 | .14572 | .08413 | 73.2347 | 73.9586 | 73.46 | 73.75 |
| | 4 | 3 | 74.2133 | .38371 | .22154 | 73.2601 | 75.1665 | 73.93 | 74.65 |
| | 6 | 3 | 74.2667 | .07506 | .04333 | 74.0802 | 74.4531 | 74.19 | 74.34 |
| | 8 | 3 | 74.4767 | .25502 | .14723 | 73.8432 | 75.1102 | 74.22 | 74.73 |
| | Total | 15 | 73.9900 | .48076 | .12413 | 73.7238 | 74.2562 | 73.23 | 74.73 |
| a* | 0 | 3 | .0333 | .00577 | .00333 | .0190 | .0477 | .03 | .04 |
| | 2 | 3 | .0267 | .00577 | .00333 | .0123 | .0410 | .02 | .03 |
| | 4 | 3 | .0133 | .00577 | .00333 | -.0010 | .0277 | .01 | .02 |
| | 6 | 3 | -.0167 | .00577 | .00333 | -.0310 | -.0023 | -.02 | -.01 |
| | 8 | 3 | -.0233 | .00577 | .00333 | -.0377 | -.0090 | -.03 | -.02 |
| | Total | 15 | .0067 | .02410 | .00622 | -.0067 | .0200 | -.03 | .04 |
| b* | 0 | 3 | 2.9933 | .04726 | .02728 | 2.8759 | 3.1107 | 2.94 | 3.03 |
| | 2 | 3 | 3.5667 | .41501 | .23961 | 2.5357 | 4.5976 | 3.15 | 3.98 |
| | 4 | 3 | 4.1367 | .48003 | .27715 | 2.9442 | 5.3291 | 3.77 | 4.68 |
| | 6 | 3 | 4.8767 | .25541 | .14746 | 4.2422 | 5.5111 | 4.59 | 5.08 |
| | 8 | 3 | 4.9567 | .30827 | .17798 | 4.1909 | 5.7225 | 4.61 | 5.20 |
| | Total | 15 | 4.1060 | .83120 | .21462 | 3.6457 | 4.5663 | 2.94 | 5.20 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| L* | Between Groups | 2.610 | 4 | .653 | 10.428 | .001 |
| | Within Groups | .626 | 10 | .063 | | |
| | Total | 3.236 | 14 | | | |
| a* | Between Groups | .008 | 4 | .002 | 58.500 | .000 |
| | Within Groups | .000 | 10 | .000 | | |
| | Total | .008 | 14 | | | |
| b* | Between Groups | 8.542 | 4 | 2.136 | 18.893 | .000 |
| | Within Groups | 1.130 | 10 | .113 | | |
| | Total | 9.673 | 14 | | | |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| L* | 2.297 | 4 | 10 | .131 |
| a* | .000 | 4 | 10 | 1.000 |
| b | 1.895 | 4 | 10 | .188 |

**Multiple Comparisons**

LSD

| Dependent Variable: Time (h) | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| L* | 0 | 2 | -.20000 | .20424 | .351 | -.6551 | .2551 |
| | | 4 | -.81667* | .20424 | .003 | -1.2718 | -.3616 |
| | | 6 | -.87000* | .20424 | .002 | -1.3251 | -.4149 |
| | | 8 | -1.08000* | .20424 | .000 | -1.5351 | -.6249 |
| | 2 | 0 | .20000 | .20424 | .351 | -.2551 | .6551 |
| | | 4 | -.61667* | .20424 | .013 | -1.0718 | -.1616 |
| | | 6 | -.67000* | .20424 | .008 | -1.1251 | -.2149 |
| | | 8 | -.88000* | .20424 | .002 | -1.3351 | -.4249 |
| | 4 | 0 | .81667* | .20424 | .003 | .3616 | 1.2718 |
| | | 2 | .61667* | .20424 | .013 | .1616 | 1.0718 |
| | | 6 | -.05333 | .20424 | .799 | -.5084 | .4018 |
| | | 8 | -.26333 | .20424 | .226 | -.7184 | .1918 |
| | 6 | 0 | .87000* | .20424 | .002 | .4149 | 1.3251 |
| | | 2 | .67000* | .20424 | .008 | .2149 | 1.1251 |
| | | 4 | .05333 | .20424 | .799 | -.4018 | .5084 |
| | | 8 | -.21000 | .20424 | .328 | -.6651 | .2451 |
| | 8 | 0 | 1.08000* | .20424 | .000 | .6249 | 1.5351 |
| | | 2 | .88000* | .20424 | .002 | .4249 | 1.3351 |
| | | 4 | .26333 | .20424 | .226 | -.1918 | .7184 |
| | | 6 | .21000 | .20424 | .328 | -.2451 | .6651 |
| a* | 0 | 2 | .00667 | .00471 | .188 | -.0038 | .0172 |
| | | 4 | .02000* | .00471 | .002 | .0095 | .0305 |
| | | 6 | .05000* | .00471 | .000 | .0395 | .0605 |
| | | 8 | .05667* | .00471 | .000 | .0462 | .0672 |
| | 2 | 0 | -.00667 | .00471 | .188 | -.0172 | .0038 |
| | | 4 | .01333* | .00471 | .018 | .0028 | .0238 |
| | | 6 | .04333* | .00471 | .000 | .0328 | .0538 |
| | | 8 | .05000* | .00471 | .000 | .0395 | .0605 |
| | 4 | 0 | -.02000* | .00471 | .002 | -.0305 | -.0095 |
| | | 2 | -.01333* | .00471 | .018 | -.0238 | -.0028 |
| | | 6 | .03000* | .00471 | .000 | .0195 | .0405 |
| | | 8 | .03667* | .00471 | .000 | .0262 | .0472 |
| | 6 | 0 | -.05000* | .00471 | .000 | -.0605 | -.0395 |
| | | 2 | -.04333* | .00471 | .000 | -.0538 | -.0328 |
| | | 4 | -.03000* | .00471 | .000 | -.0405 | -.0195 |
| | | 8 | .00667 | .00471 | .188 | -.0038 | .0172 |
| | 8 | 0 | -.05667* | .00471 | .000 | -.0672 | -.0462 |
| | | 2 | -.05000* | .00471 | .000 | -.0605 | -.0395 |
| | | 4 | -.03667* | .00471 | .000 | -.0472 | -.0262 |
| | | 6 | -.00667 | .00471 | .188 | -.0172 | .0038 |
| b | 0 | 2 | -.57333 | .27451 | .063 | -1.1850 | .0383 |
| | | 4 | -1.14333* | .27451 | .002 | -1.7550 | -.5317 |
| | | 6 | -1.88333* | .27451 | .000 | -2.4950 | -1.2717 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 8 | -1.96333* | .27451 | .000 | -2.5750 | -1.3517 |
| | 0 | .57333 | .27451 | .063 | -.0383 | 1.1850 |
| | 4 | -.57000 | .27451 | .065 | -1.1816 | .0416 |
| 2 | 6 | -1.31000* | .27451 | .001 | -1.9216 | -.6984 |
| | 8 | -1.39000* | .27451 | .000 | -2.0016 | -.7784 |
| | 0 | 1.14333* | .27451 | .002 | .5317 | 1.7550 |
| | 2 | .57000 | .27451 | .065 | -.0416 | 1.1816 |
| 4 | 6 | -.74000* | .27451 | .022 | -1.3516 | -.1284 |
| | 8 | -.82000* | .27451 | .014 | -1.4316 | -.2084 |
| | 0 | 1.88333* | .27451 | .000 | 1.2717 | 2.4950 |
| | 2 | 1.31000* | .27451 | .001 | .6984 | 1.9216 |
| 6 | 4 | .74000* | .27451 | .022 | .1284 | 1.3516 |
| | 8 | -.08000 | .27451 | .777 | -.6916 | .5316 |
| | 0 | 1.96333* | .27451 | .000 | 1.3517 | 2.5750 |
| | 2 | 1.39000* | .27451 | .000 | .7784 | 2.0016 |
| 8 | 4 | .82000* | .27451 | .014 | .2084 | 1.4316 |
| | 6 | .08000 | .27451 | .777 | -.5316 | .6916 |

*. The mean difference is significant at the 0.05 level.

## E.2.13 Statistical analysis of sugars and organic acids in fermented pea protein-coconut milk beverage during fermentation

**Descriptives**

| Fermentation time (h) | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| Sucrose concentration (% w /v) | 0 | 3 | 2.2033 | .05774 | .03333 | 2.0599 | 2.3468 | 2.17 | 2.27 |
| | 2 | 3 | 2.0567 | .05774 | .03333 | 1.9132 | 2.2001 | 1.99 | 2.09 |
| | 4 | 3 | 2.0433 | .05774 | .03333 | 1.8999 | 2.1868 | 2.01 | 2.11 |
| | 6 | 3 | 1.9333 | .05774 | .03333 | 1.7899 | 2.0768 | 1.90 | 2.00 |
| | 8 | 3 | 1.8333 | .04163 | .02404 | 1.7299 | 1.9368 | 1.80 | 1.88 |
| | Total | 15 | 2.0140 | .13710 | .03540 | 1.9381 | 2.0899 | 1.80 | 2.27 |
| Fructose concentration (% w /v) | 0 | 3 | .1433 | .00577 | .00333 | .1290 | .1577 | .14 | .15 |
| | 2 | 3 | .1700 | .01000 | .00577 | .1452 | .1948 | .16 | .18 |
| | 4 | 3 | .2133 | .01528 | .00882 | .1754 | .2513 | .20 | .23 |
| | 6 | 3 | .2433 | .02082 | .01202 | .1916 | .2950 | .22 | .26 |
| | 8 | 3 | .2667 | .02082 | .01202 | .2150 | .3184 | .25 | .29 |
| | Total | 15 | .2073 | .04891 | .01263 | .1802 | .2344 | .14 | .29 |
| Lactic acid concentration (% w /v) | 0 | 3 | .2367 | .00577 | .00333 | .2223 | .2510 | .23 | .24 |
| | 2 | 3 | .3467 | .01155 | .00667 | .3180 | .3754 | .34 | .36 |
| | 4 | 3 | .6833 | .06110 | .03528 | .5316 | .8351 | .63 | .75 |
| | 6 | 3 | .9467 | .03512 | .02028 | .8594 | 1.0339 | .91 | .98 |
| | 8 | 3 | 1.2300 | .09000 | .05196 | 1.0064 | 1.4536 | 1.14 | 1.32 |
| | Total | 15 | .6887 | .38445 | .09926 | .4758 | .9016 | .23 | 1.32 |
| Acetic acid concentration (% w /v) | 0 | 3 | 1.7300 | .15395 | .08888 | 1.3476 | 2.1124 | 1.56 | 1.86 |
| | 2 | 3 | 1.8767 | .08505 | .04910 | 1.6654 | 2.0879 | 1.78 | 1.94 |
| | 4 | 3 | 2.7067 | .11930 | .06888 | 2.4103 | 3.0030 | 2.61 | 2.84 |
| | 6 | 3 | 3.6400 | .15395 | .08888 | 3.2576 | 4.0224 | 3.51 | 3.81 |
| | 8 | 3 | 4.0100 | .17349 | .10017 | 3.5790 | 4.4410 | 3.82 | 4.16 |
| | Total | 15 | 2.7927 | .95337 | .24616 | 2.2647 | 3.3206 | 1.56 | 4.16 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Sucrose concentration (% w /v) | .303 | 4 | 10 | .870 |
| Fructose concentration (% w /v) | 1.705 | 4 | 10 | .225 |
| Lactic acid concentration (% w /v) | 2.182 | 4 | 10 | .145 |
| Acetic acid concentration (% w /v) | .502 | 4 | 10 | .736 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Sucrose concentration (% w /v) | Between Groups | .233 | 4 | .058 | 19.333 | .000 |
| | Within Groups | .030 | 10 | .003 | | |
| | Total | .263 | 14 | | | |
| Fructose concentration (% w /v) | Between Groups | .031 | 4 | .008 | 31.446 | .000 |
| | Within Groups | .002 | 10 | .000 | | |
| | Total | .033 | 14 | | | |
| Lactic acid concentration (% w /v) | Between Groups | 2.043 | 4 | .511 | 192.951 | .000 |
| | Within Groups | .026 | 10 | .003 | | |
| | Total | 2.069 | 14 | | | |
| Acetic acid concentration (% w /v) | Between Groups | 12.527 | 4 | 3.132 | 158.219 | .000 |
| | Within Groups | .198 | 10 | .020 | | |
| | Total | 12.725 | 14 | | | |

**Multiple Comparisons**

LSD

| Dependent Variable: Fermentation time (h) | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Sucrose concentration (% w /v) | 0 | 2 | .14667* | .04482 | .008 | .0468 | .2465 |
| | | 4 | .16000* | .04482 | .005 | .0601 | .2599 |
| | | 6 | .27000* | .04482 | .000 | .1701 | .3699 |
| | | 8 | .37000* | .04482 | .000 | .2701 | .4699 |
| | 2 | 0 | -.14667* | .04482 | .008 | -.2465 | -.0468 |
| | | 4 | .01333 | .04482 | .772 | -.0865 | .1132 |
| | | 6 | .12333* | .04482 | .020 | .0235 | .2232 |
| | | 8 | .22333* | .04482 | .001 | .1235 | .3232 |
| | 4 | 0 | -.16000* | .04482 | .005 | -.2599 | -.0601 |
| | | 2 | -.01333 | .04482 | .772 | -.1132 | .0865 |
| | | 6 | .11000* | .04482 | .034 | .0101 | .2099 |
| | | 8 | .21000* | .04482 | .001 | .1101 | .3099 |
| | 6 | 0 | -.27000* | .04482 | .000 | -.3699 | -.1701 |
| | | 2 | -.12333* | .04482 | .020 | -.2232 | -.0235 |
| | | 4 | -.11000* | .04482 | .034 | -.2099 | -.0101 |
| | | 8 | .10000* | .04482 | .050 | .0001 | .1999 |
| | 8 | 0 | -.37000* | .04482 | .000 | -.4699 | -.2701 |
| | | 2 | -.22333* | .04482 | .001 | -.3232 | -.1235 |
| | | 4 | -.21000* | .04482 | .001 | -.3099 | -.1101 |
| | | 6 | -.10000* | .04482 | .050 | -.1999 | -.0001 |
| Fructose concentration (% w /v) | 0 | 2 | -.02667 | .01282 | .064 | -.0552 | .0019 |
| | | 4 | -.07000* | .01282 | .000 | -.0986 | -.0414 |
| | | 6 | -.10000* | .01282 | .000 | -.1286 | -.0714 |
| | | 8 | -.12333* | .01282 | .000 | -.1519 | -.0948 |
| | 2 | 0 | .02667 | .01282 | .064 | -.0019 | .0552 |
| | | 4 | -.04333* | .01282 | .007 | -.0719 | -.0148 |
| | | 6 | -.07333* | .01282 | .000 | -.1019 | -.0448 |
| | | 8 | -.09667* | .01282 | .000 | -.1252 | -.0681 |
| | 4 | 0 | .07000* | .01282 | .000 | .0414 | .0986 |
| | | 2 | .04333* | .01282 | .007 | .0148 | .0719 |
| | | 6 | -.03000* | .01282 | .041 | -.0586 | -.0014 |
| | | 8 | -.05333* | .01282 | .002 | -.0819 | -.0248 |
| | 6 | 0 | .10000* | .01282 | .000 | .0714 | .1286 |
| | | 2 | .07333* | .01282 | .000 | .0448 | .1019 |
| | | 4 | .03000* | .01282 | .041 | .0014 | .0586 |
| | | 8 | -.02333 | .01282 | .099 | -.0519 | .0052 |
| | 8 | 0 | .12333* | .01282 | .000 | .0948 | .1519 |
| | | 2 | .09667* | .01282 | .000 | .0681 | .1252 |
| | | 4 | .05333* | .01282 | .002 | .0248 | .0819 |
| | | 6 | .02333 | .01282 | .099 | -.0052 | .0519 |
| Lactic acid concentration (% w /v) | 0 | 2 | -.11000* | .04201 | .026 | -.2036 | -.0164 |
| | | 4 | -.44667* | .04201 | .000 | -.5403 | -.3531 |
| | | 6 | -.71000* | .04201 | .000 | -.8036 | -.6164 |
| | | 8 | -.99333* | .04201 | .000 | -1.0869 | -.8997 |
| | 2 | 0 | .11000* | .04201 | .026 | .0164 | .2036 |
| | | 4 | -.33667* | .04201 | .000 | -.4303 | -.2431 |
| | | 6 | -.60000* | .04201 | .000 | -.6936 | -.5064 |
| | | 8 | -.88333* | .04201 | .000 | -.9769 | -.7897 |
| | 4 | 0 | .44667* | .04201 | .000 | .3531 | .5403 |
| | | 2 | .33667* | .04201 | .000 | .2431 | .4303 |
| | | 6 | -.26333* | .04201 | .000 | -.3569 | -.1697 |
| | | 8 | -.54667* | .04201 | .000 | -.6403 | -.4531 |
| | 6 | 0 | .71000* | .04201 | .000 | .6164 | .8036 |
| | | 2 | .60000* | .04201 | .000 | .5064 | .6936 |
| | | 4 | .26333* | .04201 | .000 | .1697 | .3569 |
| | | 8 | -.28333* | .04201 | .000 | -.3769 | -.1897 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Acetic acid concentration (% w /v) | 8 | 0 | .99333* | .04201 | .000 | .8997 | 1.0869 |
| | | 2 | .88333* | .04201 | .000 | .7897 | .9769 |
| | | 4 | .54667* | .04201 | .000 | .4531 | .6403 |
| | | 6 | .28333* | .04201 | .000 | .1897 | .3769 |
| | 0 | 2 | -.14667 | .11487 | .231 | -.4026 | .1093 |
| | | 4 | -.97667* | .11487 | .000 | -1.2326 | -.7207 |
| | | 6 | -1.91000* | .11487 | .000 | -2.1660 | -1.6540 |
| | | 8 | -2.28000* | .11487 | .000 | -2.5360 | -2.0240 |
| | 2 | 0 | .14667 | .11487 | .231 | -.1093 | .4026 |
| | | 4 | -.83000* | .11487 | .000 | -1.0860 | -.5740 |
| | | 6 | -1.76333* | .11487 | .000 | -2.0193 | -1.5074 |
| | | 8 | -2.13333* | .11487 | .000 | -2.3893 | -1.8774 |
| | 4 | 0 | .97667* | .11487 | .000 | .7207 | 1.2326 |
| | | 2 | .83000* | .11487 | .000 | .5740 | 1.0860 |
| | | 6 | -.93333* | .11487 | .000 | -1.1893 | -.6774 |
| | | 8 | -1.30333* | .11487 | .000 | -1.5593 | -1.0474 |
| | 6 | 0 | 1.91000* | .11487 | .000 | 1.6540 | 2.1660 |
| | | 2 | 1.76333* | .11487 | .000 | 1.5074 | 2.0193 |
| | | 4 | .93333* | .11487 | .000 | .6774 | 1.1893 |
| | | 8 | -.37000* | .11487 | .009 | -.6260 | -.1140 |
| | 8 | 0 | 2.28000* | .11487 | .000 | 2.0240 | 2.5360 |
| | | 2 | 2.13333* | .11487 | .000 | 1.8774 | 2.3893 |
| | | 4 | 1.30333* | .11487 | .000 | 1.0474 | 1.5593 |
| | | 6 | .37000* | .11487 | .009 | .1140 | .6260 |

*. The mean difference is significant at the 0.05 level.

E.2.14 Statistical analysis of protein content in fermented pea protein-coconut milk beverage during fermentation

**Descriptives**

Protein concentration (%)

| Time (h) | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 0 | 3 | 2.2200 | .03000 | .01732 | 2.1455 | 2.2945 | 2.19 | 2.25 |
| 2 | 3 | 2.2500 | .06000 | .03464 | 2.1010 | 2.3990 | 2.19 | 2.31 |
| 4 | 3 | 2.3133 | .06506 | .03756 | 2.1517 | 2.4750 | 2.25 | 2.38 |
| 6 | 3 | 2.3333 | .04041 | .02333 | 2.2329 | 2.4337 | 2.31 | 2.38 |
| 8 | 3 | 2.3767 | .06506 | .03756 | 2.2150 | 2.5383 | 2.31 | 2.44 |
| Total | 15 | 2.2987 | .07434 | .01919 | 2.2575 | 2.3398 | 2.19 | 2.44 |

**Test of Homogeneity of Variances**

Protein concentration (%)

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .389 | 4 | 10 | .812 |

**ANOVA**

Protein concentration (%)

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | .048 | 4 | .012 | 4.124 | .031 |
| Within Groups | .029 | 10 | .003 | | |
| Total | .077 | 14 | | | |

**Multiple Comparisons**

Dependent Variable: Protein concentration (%)

LSD

| (I) Time (h) | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 0 | 2 | -.03000 | .04412 | .512 | -.1283 | .0683 |
| | 4 | -.09333 | .04412 | .060 | -.1916 | .0050 |
| | 6 | -.11333* | .04412 | .028 | -.2116 | -.0150 |
| | 8 | -.15667* | .04412 | .005 | -.2550 | -.0584 |
| 2 | 0 | .03000 | .04412 | .512 | -.0683 | .1283 |
| | 4 | -.06333 | .04412 | .182 | -.1616 | .0350 |
| | 6 | -.08333 | .04412 | .088 | -.1816 | .0150 |
| | 8 | -.12667* | .04412 | .017 | -.2250 | -.0284 |
| 4 | 0 | .09333 | .04412 | .060 | -.0050 | .1916 |
| | 2 | .06333 | .04412 | .182 | -.0350 | .1616 |
| | 6 | -.02000 | .04412 | .660 | -.1183 | .0783 |
| | 8 | -.06333 | .04412 | .182 | -.1616 | .0350 |
| 6 | 0 | .11333* | .04412 | .028 | .0150 | .2116 |
| | 2 | .08333 | .04412 | .088 | -.0150 | .1816 |
| | 4 | .02000 | .04412 | .660 | -.0783 | .1183 |
| | 8 | -.04333 | .04412 | .349 | -.1416 | .0550 |
| 8 | 0 | .15667* | .04412 | .005 | .0584 | .2550 |
| | 2 | .12667* | .04412 | .017 | .0284 | .2250 |
| | 4 | .06333 | .04412 | .182 | -.0350 | .1616 |
| | 6 | .04333 | .04412 | .349 | -.0550 | .1416 |

*. The mean difference is significant at the 0.05 level.

## E.3 Statistical output phase 3: Stability of fermented fermented pea protein-coconut milk beverage during storage at 4 °C for 21 days

E.3.1 Statistical analysis of pH change in fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

**Descriptives**

pH

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 1 | 3 | 4.4300 | .03000 | .01732 | 4.3555 | 4.5045 | 4.40 | 4.46 |
| 7 | 3 | 4.3900 | .02000 | .01155 | 4.3403 | 4.4397 | 4.37 | 4.41 |
| 14 | 3 | 4.3600 | .04000 | .02309 | 4.2606 | 4.4594 | 4.32 | 4.40 |
| 21 | 3 | 4.3800 | .02000 | .01155 | 4.3303 | 4.4297 | 4.36 | 4.40 |
| Total | 12 | 4.3900 | .03618 | .01044 | 4.3670 | 4.4130 | 4.32 | 4.46 |

**Test of Homogeneity of Variances**

pH

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .444 | 3 | 8 | .728 |

**ANOVA**

pH

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | .008 | 3 | .003 | 3.152 | .086 |
| Within Groups | .007 | 8 | .001 | | |
| Total | .014 | 11 | | | |

**Multiple Comparisons**

Dependent Variable: pH

LSD

| (I) storage days | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 7 | .04000 | .02345 | .126 | -.0141 | .0941 |
| | 14 | .07000* | .02345 | .017 | .0159 | .1241 |
| | 21 | .05000 | .02345 | .066 | -.0041 | .1041 |
| 7 | 1 | -.04000 | .02345 | .126 | -.0941 | .0141 |
| | 14 | .03000 | .02345 | .237 | -.0241 | .0841 |
| | 21 | .01000 | .02345 | .681 | -.0441 | .0641 |
| 14 | 1 | -.07000* | .02345 | .017 | -.1241 | -.0159 |
| | 7 | -.03000 | .02345 | .237 | -.0841 | .0241 |
| | 21 | -.02000 | .02345 | .419 | -.0741 | .0341 |
| 21 | 1 | -.05000 | .02345 | .066 | -.1041 | .0041 |
| | 7 | -.01000 | .02345 | .681 | -.0641 | .0441 |
| | 14 | .02000 | .02345 | .419 | -.0341 | .0741 |

*. The mean difference is significant at the 0.05 level.

E.3.2 Statistical analysis of titratable acid change of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

**Descriptives**

T.A. (%)

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 1 | 3 | .5300 | .01000 | .00577 | .5052 | .5548 | .52 | .54 |
| 7 | 3 | .5500 | .01000 | .00577 | .5252 | .5748 | .54 | .56 |
| 14 | 3 | .5600 | .01000 | .00577 | .5352 | .5848 | .55 | .57 |
| 21 | 3 | .5467 | .00577 | .00333 | .5323 | .5610 | .54 | .55 |
| Total | 12 | .5467 | .01371 | .00396 | .5380 | .5554 | .52 | .57 |

**Test of Homogeneity of Variances**

T.A. (%)

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .143 | 3 | 8 | .931 |

**ANOVA**

T.A. (%)

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | .001 | 3 | .000 | 5.600 | .023 |
| Within Groups | .001 | 8 | .000 | | |
| Total | .002 | 11 | | | |

**Multiple Comparisons**

Dependent Variable: T.A. (%)

LSD

| (I) storage days | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 7 | -.02000* | .00745 | .028 | -.0372 | -.0028 |
| | 14 | -.03000* | .00745 | .004 | -.0472 | -.0128 |
| | 21 | -.01667 | .00745 | .056 | -.0339 | .0005 |
| 7 | 1 | .02000* | .00745 | .028 | .0028 | .0372 |
| | 14 | -.01000 | .00745 | .217 | -.0272 | .0072 |
| | 21 | .00333 | .00745 | .667 | -.0139 | .0205 |
| 14 | 1 | .03000* | .00745 | .004 | .0128 | .0472 |
| | 7 | .01000 | .00745 | .217 | -.0072 | .0272 |
| | 21 | .01333 | .00745 | .111 | -.0039 | .0305 |
| 21 | 1 | .01667 | .00745 | .056 | -.0005 | .0339 |
| | 7 | -.00333 | .00745 | .667 | -.0205 | .0139 |
| | 14 | -.01333 | .00745 | .111 | -.0305 | .0039 |

*. The mean difference is significant at the 0.05 level.

E.3.3 Statistical analysis of bacterial content of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

**Descriptives**

Bacteria quantity (Log CFU /mL)

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 1 | 3 | 8.6633 | .03512 | .02028 | 8.5761 | 8.7506 | 8.63 | 8.70 |
| 7 | 3 | 8.7067 | .02082 | .01202 | 8.6550 | 8.7584 | 8.69 | 8.73 |
| 14 | 3 | 8.7233 | .02517 | .01453 | 8.6608 | 8.7858 | 8.70 | 8.75 |
| 21 | 3 | 8.6967 | .01528 | .00882 | 8.6587 | 8.7346 | 8.68 | 8.71 |
| Total | 12 | 8.6975 | .03137 | .00906 | 8.6776 | 8.7174 | 8.63 | 8.75 |

**Test of Homogeneity of Variances**

Bacteria quantity (Log CFU /mL)

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .602 | 3 | 8 | .631 |

**ANOVA**

Bacteria quantity (Log CFU /mL)

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | .006 | 3 | .002 | 3.031 | .093 |
| Within Groups | .005 | 8 | .001 | | |
| Total | .011 | 11 | | | |

**Multiple Comparisons**

Dependent Variable: Bacteria quantity (Log CFU /mL)

LSD

| (I) Storage days | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 7 | -.04333 | .02055 | .068 | -.0907 | .0041 |
| | 14 | -.06000* | .02055 | .019 | -.1074 | -.0126 |
| | 21 | -.03333 | .02055 | .143 | -.0807 | .0141 |
| 7 | 1 | .04333 | .02055 | .068 | -.0041 | .0907 |
| | 14 | -.01667 | .02055 | .441 | -.0641 | .0307 |
| | 21 | .01000 | .02055 | .640 | -.0374 | .0574 |
| 14 | 1 | .06000* | .02055 | .019 | .0126 | .1074 |
| | 7 | .01667 | .02055 | .441 | -.0307 | .0641 |
| | 21 | .02667 | .02055 | .231 | -.0207 | .0741 |
| 21 | 1 | .03333 | .02055 | .143 | -.0141 | .0807 |
| | 7 | -.01000 | .02055 | .640 | -.0574 | .0374 |
| | 14 | -.02667 | .02055 | .231 | -.0741 | .0207 |

*. The mean difference is significant at the 0.05 level.

E.3.4 Statistical analysis of colour of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

**Descriptives**

| Colour | Store days | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| L | 1 | 3 | 74.4767 | .25502 | .14723 | 73.8432 | 75.1102 | 74.22 | 74.73 |
| | 7 | 3 | 75.3767 | .61011 | .35225 | 73.8611 | 76.8923 | 74.76 | 75.98 |
| | 14 | 3 | 75.7567 | .16803 | .09701 | 75.3393 | 76.1741 | 75.61 | 75.94 |
| | 21 | 3 | 72.4067 | 1.37264 | .79249 | 68.9968 | 75.8165 | 70.86 | 73.48 |
| | Total | 12 | 74.5042 | 1.50424 | .43424 | 73.5484 | 75.4599 | 70.86 | 75.98 |
| a | 1 | 3 | -.0233 | .00577 | .00333 | -.0377 | -.0090 | -.03 | -.02 |
| | 7 | 3 | -.0167 | .01155 | .00667 | -.0454 | .0120 | -.03 | -.01 |
| | 14 | 3 | .3133 | .00577 | .00333 | .2990 | .3277 | .31 | .32 |
| | 21 | 3 | .3767 | .07095 | .04096 | .2004 | .5529 | .30 | .44 |
| | Total | 12 | .1625 | .19452 | .05615 | .0389 | .2861 | -.03 | .44 |
| b | 1 | 3 | 4.9567 | .30827 | .17798 | 4.1909 | 5.7225 | 4.61 | 5.20 |
| | 7 | 3 | 5.1700 | .44034 | .25423 | 4.0761 | 6.2639 | 4.84 | 5.67 |
| | 14 | 3 | 4.3433 | .02887 | .01667 | 4.2716 | 4.4150 | 4.31 | 4.36 |
| | 21 | 3 | 4.1633 | .22502 | .12991 | 3.6044 | 4.7223 | 3.94 | 4.39 |
| | Total | 12 | 4.6583 | .50145 | .14476 | 4.3397 | 4.9769 | 3.94 | 5.67 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| L | 4.813 | 3 | 8 | .034 |
| a | 5.433 | 3 | 8 | .025 |
| b | 3.533 | 3 | 8 | .068 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| L | Between Groups | 20.191 | 3 | 6.730 | 11.458 | .003 |
| | Within Groups | 4.699 | 8 | .587 | | |
| | Total | 24.890 | 11 | | | |
| a | Between Groups | .406 | 3 | .135 | 103.378 | .000 |
| | Within Groups | .010 | 8 | .001 | | |
| | Total | .416 | 11 | | | |
| b | Between Groups | 2.085 | 3 | .695 | 8.168 | .008 |
| | Within Groups | .681 | 8 | .085 | | |
| | Total | 2.766 | 11 | | | |

**Multiple Comparisons**

LSD

| Dependent Variable: Store days | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| L | 1 | 7 | -.90000 | .62578 | .188 | -2.3431 | .5431 |
| | | 14 | -1.28000 | .62578 | .075 | -2.7231 | .1631 |
| | | 21 | 2.07000* | .62578 | .011 | .6269 | 3.5131 |
| | 7 | 0 | .90000 | .62578 | .188 | -.5431 | 2.3431 |
| | | 14 | -.38000 | .62578 | .561 | -1.8231 | 1.0631 |
| | | 21 | 2.97000* | .62578 | .001 | 1.5269 | 4.4131 |
| | 14 | 0 | 1.28000 | .62578 | .075 | -.1631 | 2.7231 |
| | | 7 | .38000 | .62578 | .561 | -1.0631 | 1.8231 |
| | | 21 | 3.35000* | .62578 | .001 | 1.9069 | 4.7931 |
| | 21 | 0 | -2.07000* | .62578 | .011 | -3.5131 | -.6269 |
| | | 7 | -2.97000* | .62578 | .001 | -4.4131 | -1.5269 |
| | | 14 | -3.35000* | .62578 | .001 | -4.7931 | -1.9069 |
| a | 1 | 7 | -.00667 | .02953 | .827 | -.0748 | .0614 |
| | | 14 | -.33667* | .02953 | .000 | -.4048 | -.2686 |
| | | 21 | -.40000* | .02953 | .000 | -.4681 | -.3319 |
| | 7 | 0 | .00667 | .02953 | .827 | -.0614 | .0748 |
| | | 14 | -.33000* | .02953 | .000 | -.3981 | -.2619 |
| | | 21 | -.39333* | .02953 | .000 | -.4614 | -.3252 |
| | 14 | 0 | .33667* | .02953 | .000 | .2686 | .4048 |
| | | 7 | .33000* | .02953 | .000 | .2619 | .3981 |
| | | 21 | -.06333 | .02953 | .064 | -.1314 | .0048 |
| | 21 | 0 | .40000* | .02953 | .000 | .3319 | .4681 |
| | | 7 | .39333* | .02953 | .000 | .3252 | .4614 |
| | | 14 | .06333 | .02953 | .064 | -.0048 | .1314 |
| b | 1 | 7 | -.21333 | .23819 | .397 | -.7626 | .3359 |
| | | 14 | .61333* | .23819 | .033 | .0641 | 1.1626 |
| | | 21 | .79333* | .23819 | .010 | .2441 | 1.3426 |
| | 7 | 0 | .21333 | .23819 | .397 | -.3359 | .7626 |
| | | 14 | .82667* | .23819 | .008 | .2774 | 1.3759 |
| | | 21 | 1.00667* | .23819 | .003 | .4574 | 1.5559 |
| | 14 | 0 | -.61333* | .23819 | .033 | -1.1626 | -.0641 |
| | | 7 | -.82667* | .23819 | .008 | -1.3759 | -.2774 |
| | | 21 | .18000 | .23819 | .471 | -.3693 | .7293 |
| | 21 | 0 | -.79333* | .23819 | .010 | -1.3426 | -.2441 |
| | | 7 | -1.00667* | .23819 | .003 | -1.5559 | -.4574 |
| | | 14 | -.18000 | .23819 | .471 | -.7293 | .3693 |

*. The mean difference is significant at the 0.05 level.

E.3.5 Statistical analysis of sugar and organic acid change of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

**Descriptives**

| Storage days | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| Sucrose concentration (% w /v) | 1 | 3 | 3.0467 | .02517 | .01453 | 2.9842 | 3.1092 | 3.02 | 3.07 |
| | 7 | 3 | 2.8000 | .05000 | .02887 | 2.6758 | 2.9242 | 2.75 | 2.85 |
| | 14 | 3 | 2.4200 | .01000 | .00577 | 2.3952 | 2.4448 | 2.41 | 2.43 |
| | 21 | 3 | 1.6833 | .00577 | .00333 | 1.6690 | 1.6977 | 1.68 | 1.69 |
| | Total | 12 | 2.4875 | .53862 | .15549 | 2.1453 | 2.8297 | 1.68 | 3.07 |
| Fructose concentration (% w /v) | 1 | 3 | .1833 | .02517 | .01453 | .1208 | .2458 | .16 | .21 |
| | 7 | 3 | .2267 | .03055 | .01764 | .1508 | .3026 | .20 | .26 |
| | 14 | 3 | .2467 | .02517 | .01453 | .1842 | .3092 | .22 | .27 |
| | 21 | 3 | .2667 | .02517 | .01453 | .2042 | .3292 | .24 | .29 |
| | Total | 12 | .2308 | .03942 | .01138 | .2058 | .2559 | .16 | .29 |
| Lactic acid concentration (% w /v) | 1 | 3 | 1.4067 | .03512 | .02028 | 1.3194 | 1.4939 | 1.37 | 1.44 |
| | 7 | 3 | 1.3633 | .00577 | .00333 | 1.3490 | 1.3777 | 1.36 | 1.37 |
| | 14 | 3 | 1.3500 | .02000 | .01155 | 1.3003 | 1.3997 | 1.33 | 1.37 |
| | 21 | 3 | 1.3233 | .03512 | .02028 | 1.2361 | 1.4106 | 1.29 | 1.36 |
| | Total | 12 | 1.3608 | .03895 | .01125 | 1.3361 | 1.3856 | 1.29 | 1.44 |
| Acetic acid concentration (% w /v) | 1 | 3 | 2.6133 | .02517 | .01453 | 2.5508 | 2.6758 | 2.59 | 2.64 |
| | 7 | 3 | 2.5200 | .05000 | .02887 | 2.3958 | 2.6442 | 2.47 | 2.57 |
| | 14 | 3 | 2.4800 | .04000 | .02309 | 2.3806 | 2.5794 | 2.44 | 2.52 |
| | 21 | 3 | 2.1167 | .00577 | .00333 | 2.1023 | 2.1310 | 2.11 | 2.12 |
| | Total | 12 | 2.4325 | .19923 | .05751 | 2.3059 | 2.5591 | 2.11 | 2.64 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Sucrose concentration (% w /v) | 2.034 | 3 | 8 | .188 |
| Fructose concentration (% w /v) | .088 | 3 | 8 | .964 |
| Lactic acid concentration (% w /v) | 1.388 | 3 | 8 | .315 |
| Acetic acid concentration (% w /v) | 1.224 | 3 | 8 | .363 |

**Multiple Comparisons**

LSD

| Dependent | Storage days | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Sucrose concentration (% w /v) | 1 | 7 | .24667* | .02333 | .000 | .1929 | .3005 |
| | | 14 | .62667* | .02333 | .000 | .5729 | .6805 |
| | | 21 | 1.36333* | .02333 | .000 | 1.3095 | 1.4171 |
| | 7 | 1 | -.24667* | .02333 | .000 | -.3005 | -.1929 |
| | | 14 | .38000* | .02333 | .000 | .3262 | .4338 |
| | | 21 | 1.11667* | .02333 | .000 | 1.0629 | 1.1705 |
| | 14 | 1 | -.62667* | .02333 | .000 | -.6805 | -.5729 |
| | | 7 | -.38000* | .02333 | .000 | -.4338 | -.3262 |
| | | 21 | .73667* | .02333 | .000 | .6829 | .7905 |
| | 21 | 1 | -1.36333* | .02333 | .000 | -1.4171 | -1.3095 |
| | | 7 | -1.11667* | .02333 | .000 | -1.1705 | -1.0629 |
| | | 14 | -.73667* | .02333 | .000 | -.7905 | -.6829 |
| Fructose concentration (% w /v) | 1 | 7 | -.04333 | .02173 | .081 | -.0934 | .0068 |
| | | 14 | -.06333* | .02173 | .019 | -.1134 | -.0132 |
| | | 21 | -.08333* | .02173 | .005 | -.1334 | -.0332 |
| | 7 | 1 | .04333 | .02173 | .081 | -.0068 | .0934 |
| | | 14 | -.02000 | .02173 | .384 | -.0701 | .0301 |
| | | 21 | -.04000 | .02173 | .103 | -.0901 | .0101 |
| | 14 | 1 | .06333* | .02173 | .019 | .0132 | .1134 |
| | | 7 | .02000 | .02173 | .384 | -.0301 | .0701 |
| | | 21 | -.02000 | .02173 | .384 | -.0701 | .0301 |
| | 21 | 1 | .08333* | .02173 | .005 | .0332 | .1334 |
| | | 7 | .04000 | .02173 | .103 | -.0101 | .0901 |
| | | 14 | .02000 | .02173 | .384 | -.0301 | .0701 |
| Lactic acid concentration (% w /v) | 1 | 7 | .04333 | .02198 | .084 | -.0074 | .0940 |
| | | 14 | .05667* | .02198 | .033 | .0060 | .1074 |
| | | 21 | .08333* | .02198 | .005 | .0326 | .1340 |
| | 7 | 1 | -.04333 | .02198 | .084 | -.0940 | .0074 |
| | | 14 | .01333 | .02198 | .561 | -.0374 | .0640 |
| | | 21 | .04000 | .02198 | .106 | -.0107 | .0907 |
| | 14 | 1 | -.05667* | .02198 | .033 | -.1074 | -.0060 |
| | | 7 | -.01333 | .02198 | .561 | -.0640 | .0374 |
| | | 21 | .02667 | .02198 | .260 | -.0240 | .0774 |
| | 21 | 1 | -.08333* | .02198 | .005 | -.1340 | -.0326 |
| | | 7 | -.04000 | .02198 | .106 | -.0907 | .0107 |
| | | 14 | -.02667 | .02198 | .260 | -.0774 | .0240 |
| Acetic acid concentration (% w /v) | 1 | 7 | .09333* | .02819 | .011 | .0283 | .1583 |
| | | 14 | .13333* | .02819 | .001 | .0683 | .1983 |
| | | 21 | .49667* | .02819 | .000 | .4317 | .5617 |
| | 7 | 1 | -.09333* | .02819 | .011 | -.1583 | -.0283 |
| | | 14 | .04000 | .02819 | .194 | -.0250 | .1050 |
| | | 21 | .40333* | .02819 | .000 | .3383 | .4683 |
| | 14 | 1 | -.13333* | .02819 | .001 | -.1983 | -.0683 |
| | | 7 | -.04000 | .02819 | .194 | -.1050 | .0250 |
| | | 21 | .36333* | .02819 | .000 | .2983 | .4283 |
| | 21 | 1 | -.49667* | .02819 | .000 | -.5617 | -.4317 |
| | | 7 | -.40333* | .02819 | .000 | -.4683 | -.3383 |
| | | 14 | -.36333* | .02819 | .000 | -.4283 | -.2983 |

*. The mean difference is significant at the 0.05 level.

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Sucrose concentration (% w /v) | Between Groups | 3.185 | 3 | 1.062 | 1299.874 | .000 |
| | Within Groups | .007 | 8 | .001 | | |
| | Total | 3.191 | 11 | | | |
| Fructose concentration (% w /v) | Between Groups | .011 | 3 | .004 | 5.376 | .025 |
| | Within Groups | .006 | 8 | .001 | | |
| | Total | .017 | 11 | | | |
| Lactic acid concentration (% w /v) | Between Groups | .011 | 3 | .004 | 5.008 | .030 |
| | Within Groups | .006 | 8 | .001 | | |
| | Total | .017 | 11 | | | |
| Acetic acid concentration (% w /v) | Between Groups | .427 | 3 | .142 | 119.466 | .000 |
| | Within Groups | .010 | 8 | .001 | | |
| | Total | .437 | 11 | | | |

F.3.6 Statistical analysis of protein content of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

**Descriptives**

Protein concentration（%）

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| 1 | 3 | 2.0000 | .06000 | .03464 | 1.8510 | 2.1490 | 1.94 | 2.06 |
| 7 | 3 | 2.0200 | .03464 | .02000 | 1.9339 | 2.1061 | 2.00 | 2.06 |
| 14 | 3 | 2.0400 | .03464 | .02000 | 1.9539 | 2.1261 | 2.00 | 2.06 |
| 21 | 3 | 2.0833 | .04041 | .02333 | 1.9829 | 2.1837 | 2.06 | 2.13 |
| Total | 12 | 2.0358 | .04926 | .01422 | 2.0045 | 2.0671 | 1.94 | 2.13 |

**Test of Homogeneity of Variances**

Protein concentration（%）

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .288 | 3 | 8 | .833 |

**ANOVA**

Protein concentration （%）

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | .011 | 3 | .004 | 1.996 | .193 |
| Within Groups | .015 | 8 | .002 | | |
| Total | .027 | 11 | | | |

**Multiple Comparisons**

Dependent Variable: Protein concentration （%）

LSD

| (I) Storage days | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 7 | -.02000 | .03567 | .590 | -.1023 | .0623 |
| | 14 | -.04000 | .03567 | .295 | -.1223 | .0423 |
| | 21 | -.08333* | .03567 | .048 | -.1656 | -.0011 |
| 7 | 1 | .02000 | .03567 | .590 | -.0623 | .1023 |
| | 14 | -.02000 | .03567 | .590 | -.1023 | .0623 |
| | 21 | -.06333 | .03567 | .114 | -.1456 | .0189 |
| 14 | 1 | .04000 | .03567 | .295 | -.0423 | .1223 |
| | 7 | .02000 | .03567 | .590 | -.0623 | .1023 |
| | 21 | -.04333 | .03567 | .259 | -.1256 | .0389 |
| 21 | 1 | .08333* | .03567 | .048 | .0011 | .1656 |
| | 7 | .06333 | .03567 | .114 | -.0189 | .1456 |
| | 14 | .04333 | .03567 | .259 | -.0389 | .1256 |

*. The mean difference is significant at the 0.05 level.

## E.3.7 Statistical analysis of semi-trained sensory panel (n=15) sensory evaluation of fermented pea protein-coconut milk beverage during storage (4 °C) for 21 days

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Appearance | 1.477 | 3 | 56 | .231 |
| Aroma | 4.269 | 3 | 56 | .009 |
| Sourness | 3.538 | 3 | 56 | .020 |
| Sweetness | 2.051 | 3 | 56 | .117 |
| Flavour | 8.682 | 3 | 56 | .000 |
| Mouth feel | 4.304 | 3 | 56 | .008 |
| After taste | 2.222 | 3 | 56 | .096 |
| Overall acceptability | 4.000 | 3 | 56 | .012 |

**Descriptives**

| Store days | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| Appearance | 1 | 15 | 7.0000 | 1.25357 | .32367 | 6.3058 | 7.6942 | 5.00 | 9.00 |
| | 7 | 15 | 6.8000 | .67612 | .17457 | 6.4256 | 7.1744 | 6.00 | 8.00 |
| | 14 | 15 | 6.6000 | .82808 | .21381 | 6.1414 | 7.0586 | 6.00 | 8.00 |
| | 21 | 15 | 6.0000 | .92582 | .23905 | 5.4873 | 6.5127 | 4.00 | 8.00 |
| | Total | 60 | 6.6000 | .99490 | .12844 | 6.3430 | 6.8570 | 4.00 | 9.00 |
| Aroma | 1 | 15 | 7.0000 | 1.30931 | .33806 | 6.2749 | 7.7251 | 6.00 | 9.00 |
| | 7 | 15 | 6.8000 | .67612 | .17457 | 6.4256 | 7.1744 | 6.00 | 8.00 |
| | 14 | 15 | 7.0000 | 1.00000 | .25820 | 6.4462 | 7.5538 | 5.00 | 8.00 |
| | 21 | 15 | 7.0000 | .92582 | .23905 | 6.4873 | 7.5127 | 5.00 | 8.00 |
| | Total | 60 | 6.9500 | .98161 | .12673 | 6.6964 | 7.2036 | 5.00 | 9.00 |
| Sourness | 1 | 15 | 5.0000 | 1.19523 | .30861 | 4.3381 | 5.6619 | 4.00 | 7.00 |
| | 7 | 15 | 6.0667 | .70373 | .18170 | 5.6770 | 6.4564 | 5.00 | 7.00 |
| | 14 | 15 | 6.2000 | 1.20712 | .31168 | 5.5315 | 6.8685 | 4.00 | 7.00 |
| | 21 | 15 | 6.4000 | 1.12122 | .28950 | 5.7791 | 7.0209 | 5.00 | 8.00 |
| | Total | 60 | 5.9167 | 1.18310 | .15274 | 5.6110 | 6.2223 | 4.00 | 8.00 |
| Sweetness | 1 | 15 | 6.2000 | 1.01419 | .26186 | 5.6384 | 6.7616 | 5.00 | 8.00 |
| | 7 | 15 | 6.4000 | .91026 | .23503 | 5.8959 | 6.9041 | 5.00 | 8.00 |
| | 14 | 15 | 6.4000 | .82808 | .21381 | 5.9414 | 6.8586 | 5.00 | 7.00 |
| | 21 | 15 | 6.2000 | .56061 | .14475 | 5.8895 | 6.5105 | 5.00 | 7.00 |
| | Total | 60 | 6.3000 | .82954 | .10709 | 6.0857 | 6.5143 | 5.00 | 8.00 |
| Flavour | 1 | 15 | 6.0000 | 1.46385 | .37796 | 5.1893 | 6.8107 | 4.00 | 8.00 |
| | 7 | 15 | 6.4000 | .50709 | .13093 | 6.1192 | 6.6808 | 6.00 | 7.00 |
| | 14 | 15 | 6.2000 | .56061 | .14475 | 5.8895 | 6.5105 | 5.00 | 7.00 |
| | 21 | 15 | 6.8000 | .67612 | .17457 | 6.4256 | 7.1744 | 5.00 | 8.00 |
| | Total | 60 | 6.3500 | .91735 | .11843 | 6.1130 | 6.5870 | 4.00 | 8.00 |
| Mouth feel | 1 | 15 | 6.2000 | 1.08233 | .27946 | 5.6006 | 6.7994 | 4.00 | 7.00 |
| | 7 | 15 | 6.4000 | 1.50238 | .38791 | 5.5680 | 7.2320 | 4.00 | 8.00 |
| | 14 | 15 | 6.4000 | .50709 | .13093 | 6.1192 | 6.6808 | 6.00 | 7.00 |
| | 21 | 15 | 7.2000 | .94112 | .24300 | 6.6788 | 7.7212 | 5.00 | 8.00 |
| | Total | 60 | 6.5500 | 1.11119 | .14345 | 6.2629 | 6.8371 | 4.00 | 8.00 |
| After taste | 1 | 15 | 6.8000 | 1.14642 | .29601 | 6.1651 | 7.4349 | 6.00 | 9.00 |
| | 7 | 15 | 6.0000 | 1.00000 | .25820 | 5.4462 | 6.5538 | 5.00 | 8.00 |
| | 14 | 15 | 6.2000 | 1.20712 | .31168 | 5.5315 | 6.8685 | 5.00 | 8.00 |
| | 21 | 15 | 7.0000 | .84515 | .21822 | 6.5320 | 7.4680 | 5.00 | 8.00 |
| | Total | 60 | 6.5000 | 1.11233 | .14360 | 6.2127 | 6.7873 | 5.00 | 9.00 |
| Overall acceptability | 1 | 15 | 6.8000 | .94112 | .24300 | 6.2788 | 7.3212 | 6.00 | 8.00 |
| | 7 | 15 | 6.6000 | .73679 | .19024 | 6.1920 | 7.0080 | 5.00 | 8.00 |
| | 14 | 15 | 6.6000 | .50709 | .13093 | 6.3192 | 6.8808 | 6.00 | 7.00 |
| | 21 | 15 | 6.2000 | .67612 | .17457 | 5.8256 | 6.5744 | 5.00 | 7.00 |
| | Total | 60 | 6.5500 | .74618 | .09633 | 6.3572 | 6.7428 | 5.00 | 8.00 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Appearance | Between Groups | 8.400 | 3 | 2.800 | 3.136 | .032 |
| | Within Groups | 50.000 | 56 | .893 | | |
| | Total | 58.400 | 59 | | | |
| Aroma | Between Groups | .450 | 3 | .150 | .149 | .930 |
| | Within Groups | 56.400 | 56 | 1.007 | | |
| | Total | 56.850 | 59 | | | |
| Sourness | Between Groups | 17.650 | 3 | 5.883 | 5.074 | .004 |
| | Within Groups | 64.933 | 56 | 1.160 | | |
| | Total | 82.583 | 59 | | | |
| Sweetness | Between Groups | .600 | 3 | .200 | .280 | .840 |
| | Within Groups | 40.000 | 56 | .714 | | |
| | Total | 40.600 | 59 | | | |
| Flavour | Between Groups | 5.250 | 3 | 1.750 | 2.207 | .097 |
| | Within Groups | 44.400 | 56 | .793 | | |
| | Total | 49.650 | 59 | | | |
| Mouth feel | Between Groups | 8.850 | 3 | 2.950 | 2.581 | .062 |
| | Within Groups | 64.000 | 56 | 1.143 | | |
| | Total | 72.850 | 59 | | | |
| After taste | Between Groups | 10.200 | 3 | 3.400 | 3.032 | .037 |
| | Within Groups | 62.800 | 56 | 1.121 | | |
| | Total | 73.000 | 59 | | | |
| Overall acceptability | Between Groups | 2.850 | 3 | .950 | 1.773 | .163 |
| | Within Groups | 30.000 | 56 | .536 | | |
| | Total | 32.850 | 59 | | | |

**Multiple Comparisons**

LSD

| Dependent Variable: Store days | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Appearance | 1 | 7 | .20000 | .34503 | .564 | -.4912 | .8912 |
| | | 14 | .40000 | .34503 | .251 | -.2912 | 1.0912 |
| | | 21 | 1.00000* | .34503 | .005 | .3088 | 1.6912 |
| | 7 | 1 | -.20000 | .34503 | .564 | -.8912 | .4912 |
| | | 14 | .20000 | .34503 | .564 | -.4912 | .8912 |
| | | 21 | .80000* | .34503 | .024 | .1088 | 1.4912 |
| | 14 | 1 | -.40000 | .34503 | .251 | -1.0912 | .2912 |
| | | 7 | -.20000 | .34503 | .564 | -.8912 | .4912 |
| | | 21 | .60000 | .34503 | .088 | -.0912 | 1.2912 |
| | 21 | 1 | -1.00000* | .34503 | .005 | -1.6912 | -.3088 |
| | | 7 | -.80000* | .34503 | .024 | -1.4912 | -.1088 |
| | | 14 | -.60000 | .34503 | .088 | -1.2912 | .0912 |
| Aroma | 1 | 7 | .20000 | .36645 | .587 | -.5341 | .9341 |
| | | 14 | 0.00000 | .36645 | 1.000 | -.7341 | .7341 |
| | | 21 | 0.00000 | .36645 | 1.000 | -.7341 | .7341 |
| | 7 | 1 | -.20000 | .36645 | .587 | -.9341 | .5341 |
| | | 14 | -.20000 | .36645 | .587 | -.9341 | .5341 |
| | | 21 | -.20000 | .36645 | .587 | -.9341 | .5341 |
| | 14 | 1 | 0.00000 | .36645 | 1.000 | -.7341 | .7341 |
| | | 7 | .20000 | .36645 | .587 | -.5341 | .9341 |
| | | 21 | 0.00000 | .36645 | 1.000 | -.7341 | .7341 |
| | 21 | 1 | 0.00000 | .36645 | 1.000 | -.7341 | .7341 |
| | | 7 | .20000 | .36645 | .587 | -.5341 | .9341 |
| | | 14 | 0.00000 | .36645 | 1.000 | -.7341 | .7341 |
| Sourness | 1 | 7 | -1.06667* | .39320 | .009 | -1.8543 | -.2790 |
| | | 14 | -1.20000* | .39320 | .003 | -1.9877 | -.4123 |
| | | 21 | -1.40000* | .39320 | .001 | -2.1877 | -.6123 |
| | 7 | 1 | 1.06667* | .39320 | .009 | .2790 | 1.8543 |
| | | 14 | -.13333 | .39320 | .736 | -.9210 | .6543 |
| | | 21 | -.33333 | .39320 | .400 | -1.1210 | .4543 |
| | 14 | 1 | 1.20000* | .39320 | .003 | .4123 | 1.9877 |
| | | 7 | .13333 | .39320 | .736 | -.6543 | .9210 |
| | | 21 | -.20000 | .39320 | .613 | -.9877 | .5877 |
| | 21 | 1 | 1.40000* | .39320 | .001 | .6123 | 2.1877 |
| | | 7 | .33333 | .39320 | .400 | -.4543 | 1.1210 |
| | | 14 | .20000 | .39320 | .613 | -.5877 | .9877 |
| Sweetness | 1 | 7 | -.20000 | .30861 | .520 | -.8182 | .4182 |
| | | 14 | -.20000 | .30861 | .520 | -.8182 | .4182 |
| | | 21 | 0.00000 | .30861 | 1.000 | -.6182 | .6182 |
| | 7 | 1 | .20000 | .30861 | .520 | -.4182 | .8182 |
| | | 14 | 0.00000 | .30861 | 1.000 | -.6182 | .6182 |
| | | 21 | .20000 | .30861 | .520 | -.4182 | .8182 |
| | 14 | 1 | .20000 | .30861 | .520 | -.4182 | .8182 |
| | | 7 | 0.00000 | .30861 | 1.000 | -.6182 | .6182 |
| | | 21 | .20000 | .30861 | .520 | -.4182 | .8182 |
| | 21 | 1 | 0.00000 | .30861 | 1.000 | -.6182 | .6182 |
| | | 7 | -.20000 | .30861 | .520 | -.8182 | .4182 |
| | | 14 | -.20000 | .30861 | .520 | -.8182 | .4182 |
| Flavour | 1 | 7 | -.40000 | .32514 | .224 | -1.0513 | .2513 |
| | | 14 | -.20000 | .32514 | .541 | -.8513 | .4513 |
| | | 21 | -.80000* | .32514 | .017 | -1.4513 | -.1487 |
| | 7 | 1 | .40000 | .32514 | .224 | -.2513 | 1.0513 |
| | | 14 | .20000 | .32514 | .541 | -.4513 | .8513 |
| | | 21 | -.40000 | .32514 | .224 | -1.0513 | .2513 |
| | 14 | 1 | .20000 | .32514 | .541 | -.4513 | .8513 |
| | | 7 | -.20000 | .32514 | .541 | -.8513 | .4513 |
| | | 21 | -.60000 | .32514 | .070 | -1.2513 | .0513 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | .80000* | .32514 | .017 | .1487 | 1.4513 |
| | 21 | 7 | .40000 | .32514 | .224 | -.2513 | 1.0513 |
| | | 14 | .60000 | .32514 | .070 | -.0513 | 1.2513 |
| | | 7 | -.20000 | .39036 | .610 | -.9820 | .5820 |
| | 1 | 14 | -.20000 | .39036 | .610 | -.9820 | .5820 |
| | | 21 | -1.00000* | .39036 | .013 | -1.7820 | -.2180 |
| | | 1 | .20000 | .39036 | .610 | -.5820 | .9820 |
| | 7 | 14 | 0.00000 | .39036 | 1.000 | -.7820 | .7820 |
| | | 21 | -.80000* | .39036 | .045 | -1.5820 | -.0180 |
| Mouth feel | | 1 | .20000 | .39036 | .610 | -.5820 | .9820 |
| | 14 | 7 | 0.00000 | .39036 | 1.000 | -.7820 | .7820 |
| | | 21 | -.80000* | .39036 | .045 | -1.5820 | -.0180 |
| | | 1 | 1.00000* | .39036 | .013 | .2180 | 1.7820 |
| | 21 | 7 | .80000* | .39036 | .045 | .0180 | 1.5820 |
| | | 14 | .80000* | .39036 | .045 | .0180 | 1.5820 |
| | | 7 | .80000* | .38668 | .043 | .0254 | 1.5746 |
| | 1 | 14 | .60000 | .38668 | .126 | -.1746 | 1.3746 |
| | | 21 | -.20000 | .38668 | .607 | -.9746 | .5746 |
| | | 1 | -.80000* | .38668 | .043 | -1.5746 | -.0254 |
| | 7 | 14 | -.20000 | .38668 | .607 | -.9746 | .5746 |
| | | 21 | -1.00000* | .38668 | .012 | -1.7746 | -.2254 |
| After taste | | 1 | -.60000 | .38668 | .126 | -1.3746 | .1746 |
| | 14 | 7 | .20000 | .38668 | .607 | -.5746 | .9746 |
| | | 21 | -.80000* | .38668 | .043 | -1.5746 | -.0254 |
| | | 1 | .20000 | .38668 | .607 | -.5746 | .9746 |
| | 21 | 7 | 1.00000* | .38668 | .012 | .2254 | 1.7746 |
| | | 14 | .80000* | .38668 | .043 | .0254 | 1.5746 |
| | | 7 | .20000 | .26726 | .457 | -.3354 | .7354 |
| | 1 | 14 | .20000 | .26726 | .457 | -.3354 | .7354 |
| | | 21 | .60000* | .26726 | .029 | .0646 | 1.1354 |
| | | 1 | -.20000 | .26726 | .457 | -.7354 | .3354 |
| | 7 | 14 | 0.00000 | .26726 | 1.000 | -.5354 | .5354 |
| | | 21 | .40000 | .26726 | .140 | -.1354 | .9354 |
| Overall acceptability | | 1 | -.20000 | .26726 | .457 | -.7354 | .3354 |
| | 14 | 7 | 0.00000 | .26726 | 1.000 | -.5354 | .5354 |
| | | 21 | .40000 | .26726 | .140 | -.1354 | .9354 |
| | | 1 | -.60000* | .26726 | .029 | -1.1354 | -.0646 |
| | 21 | 7 | -.40000 | .26726 | .140 | -.9354 | .1354 |
| | | 14 | -.40000 | .26726 | .140 | -.9354 | .1354 |

*. The mean difference is significant at the 0.05 level.